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(54) **Communications satellite router-formatter**

(57) A local telecommunications network is provided for satellite based telecommunications. The network 10 includes multiple handsets 18-22, 50 and 54 which communicate directly with ground stations 14 and 16. The ground stations communicate with an overhead satellite 12 through a satellite telecommunications uplink. The ground stations include a router for determining whether outgoing calls are directed to a destination handset located within or outside a predefined local geographic cell 30 and 32 for the corresponding ground station 14 and 16. If the destination handset is located outside the local cell of the originating handset, the ground station passes the call to the overhead satellite 12 to establish a satellite telecommunications link. However, if the destination handset 50 is located within the same local cell 32 as the originating handset 22, then the router 16 establishes a direct link between the handsets 22 and 50 without establishing a satellite telecommunications link 26.

EP 0 797 319 A2

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Description**Field of the Invention**

The present invention generally relates to a satellite based telecommunications system. More specifically, the invention relates to a telecommunications satellite system containing a device, such as a local ground station, which serves as a router-formatter for communications between the satellite and local handsets.

Background of the Invention

With the advent of modern telecommunications technology, telecommunications services are being offered in more and more remote regions of the world. Telecommunications services have been offered to these remote areas in a variety of ways. For instance, several satellite based systems have been proposed to enable direct communication between handsets and the satellite even when the mobile station is located in a region of the world far removed from wire-based or cellular telephone services. As proposed, the foregoing satellite systems include individual user handsets which afford bidirectional communication directly with the telecommunications satellite. The handsets do not communicate directly with any other handset. The term "handset" as used throughout includes mobile stations, portable phones, cellular phones, wire-based stationary phones, faxes, modems and the like.

However, the current handset-to-satellite link is considered to have certain limitations, particularly with respect to signal blockage. In order to effect direct communication between the handset and satellite, the communications link requires an unobstructed line of sight therebetween or an "open sky" void of obstructions, such as buildings, trees and the like. Such intervening structures interfere with the communications link. To minimize the risk of obstructions between the satellite and handset, the handsets should be used in open areas away from large buildings. Alternatively, the handsets may be attached to stationary antennas, such as a rooftop omni or dish-type antenna. However, such connections greatly constrain the portability of the handsets, thereby rendering the handset a stationary unit. Stationary units may have limited use, such as in regions which do not have existing telephone infrastructures or in areas where the existing telephone system is prohibitively expensive and/or unreliable. However, a telephone system consisting of stationary units would be less economical and require more satellite links than the proposed invention.

Moreover, notwithstanding the use of stationary roof mounted antennas, the stationary units heretofore proposed still experience limitations, due to the use of an asynchronous communications uplink. More specifically, the telecommunications satellite systems thus far proposed contemplate using a synchronous down link when the satellite transmits data to the mobile station.

However, each satellite must receive uplink communications data from a large number of individual mobile stations. Some proposed systems (Iridium and Global Star) contemplate using asynchronous uplinks. Another proposed system (Odyssey, proposed by the assignee of the present application) contemplates using synchronous uplinks. The concept of synchronous and non-synchronous communications are explained in more detail in the book entitled "Satellite Communications Systems" by Marai et al., published by John Wiley & Sons, New York, NY (1986), and in the book entitled "An Introduction to GSM" by Redl et al., published by Artech House Publishers, Boston, MA (1995). Both of the above-referenced books are expressly incorporated by reference in their entirety. Synchronous communications are achieved based on timing information provided to all mobile stations. The timing information is provided separately to each mobile station. The timing information controls advancements and retardation of the time at which a mobile station begins transmission to ensure that the data is received synchronously from all transmitting mobile stations. Timing information is generally used in connection with synchronous return links from mobile stations.

When using non-synchronous uplinks, the system greatly limits the capacity of the uplink as compared to a synchronous uplink. Non-synchronous direct sequence spread spectrum communications links experience substantially greater co-channel interference as compared to synchronous links. To minimize the co-channel interference, the system typically employs substantial forward error correction encoding and limits the number of mobile stations supported by the satellite, thereby decreasing the system's capacity and economical viability. When using synchronous uplinks, the proposed systems (Odyssey) require complex circuitry to be installed in each mobile station to control timing advancements and retardations and individual handset output power. This synchronization and power control circuitry increases the complexity and cost of each handset.

In addition, portable handsets have a limited battery dependent power supply, thereby limiting the maximum achievable output power level and duration of portable service. Satellite based telecommunications systems, such as the Odyssey system, contemplate using low power generally omni-directional antennas with the mobile stations. Such omni-directional antennas transmit outgoing communications typically with more or less the same power in all directions. These omni-directional or hemisphere coverage antennas may operate at power levels as low as one-half watt. These power constraints further render the communications link with the handset susceptible to line of sight obstructions between the handset and satellite.

Moreover, the proposed satellite based telecommunications systems require unduly excessive communications traffic with the satellite. Generally, communications links in satellite based systems may be

categorized into (1) local calls between two local handsets located within a relatively small geographic area, and (2) long distance calls between one local handset and a remote destination handset. The terms "local" and "remote" as used throughout this application are used relative to a predefined geographic area or cell surrounding the handset initiating the call. If the destination handset falls within this geographic area, the call is deemed local. Otherwise, the call is deemed remote or long distance.

The proposed satellite based systems route all outgoing calls from an initiating handset through a corresponding satellite located overhead the initiating handset. The satellite then transmits each call to a network ground or earth station which decodes the call destination. If the destination is also a PCS satellite handset, it determines which satellite and ground station connections are necessary to direct the call to the destination handset. The network ground station is connected to a PSTN network. If the destination handset is also local, the network ground station transmits the signal back to the overhead satellite above the predefined geographic area surrounding the initiating handset. The satellite transmits the call to the destination handset. If the destination handset is remote, the network ground station may transmit the call via wireline network and a ground station and/or satellite. Thus, all calls must be routed through the overhead satellite and network ground station, regardless of whether the destination handset is local or remote. Such routing unnecessarily increases the traffic which must be supported by the satellite and network ground stations.

Conventional systems have failed to address the deficiencies noted above within the field of satellite based telecommunications. Examples of existing systems are disclosed in USP 5,173,933 and USP 5,412,600 both of which are expressly incorporated by reference in their entirety.

The '660 patent discloses a satellite based ISDN network. The network includes a plurality of portable satellite terminals which receive and transmit communications which conform to the ISDN industry standard and which operate with standard ISDN equipment. The network of the '660 patent extends the public service telephone network (PSTN) access to isolated single terminals. However, the '660 patent is not concerned with extending PSTN access to a remote community with multiple users therein, and hence is not concerned with providing remote intra-community communications paths without accessing overhead satellites. Instead, the system of the '660 patent transmits all ISDN data via the satellite without distinguishing between remote and local destinations.

The '933 patent discloses an interface between mobile telecommunications stations and trunk channels linked to various communications carriers, such as a satellite dish, a cellular line antenna and the like. The interface automatically selects the most cost-effective carrier upon which to transmit an outgoing telephone or

fax transmission from a mobile station. However, the interface of the '933 patent does not distinguish between local and remote destinations. Nor does the interface of the '933 patent bypass the satellite or antenna for entirely local calls. Instead, the interface of the '933 patent is intended solely for remote calls, namely calls which must be relayed through a satellite or similar communications carrier. The '933 patent is intended for implementation upon an oceangoing vessel and is intended to provide a communications link between callers on the vessel and parties on shore. The communications system of the '933 patent is not concerned with intra-ship communications. Thus, the interface of the '933 patent does not provide a local community with a low cost telecommunications infrastructure.

A need remains for an improved satellite based telecommunications system for use in a remote community than can economically interface with or provide the basis for a wired or wireless/cellular-type telecommunications infrastructure. It is an object of the present invention to meet this need.

Summary of the Invention

It is an object of the present invention to provide a telecommunications satellite based system containing a base station which controls routing and formatting of communications between an overhead satellite and local handsets to provide an economic communications infrastructure for a remote community.

It is another object of the present invention to provide a routing module which reduces the communications traffic to and from the satellites in order to increase the system's overall capacity by judicious use of satellite resources.

It is a corollary object of the present invention to minimize uplink communications traffic by distinguishing between local and remote destinations for outgoing calls and redirecting, within the base station, local calls to the local destination without use of the satellite.

It is yet another object of the present invention to provide a router/formatter which may enhance communications uplinks by utilizing a high-power steerable beam or phased array type antenna.

It is a corollary object of the present invention to provide a wireless telecommunications infrastructure for a remote community capable of utilizing handsets, such as portable or cellular phones which operate according to a conventional standard.

It is yet a further object of the present invention to utilize economic handsets which are greatly reduced in complexity and need not rely on line of sight communications or maintain synchronous communications links with a satellite.

It is a further object of the present invention to provide a router/formatter module which maintains consistent line of sight access with the satellite.

It is a further corollary object of the present inven-

tion to provide a formatter/router module which affords an easy and economical centralized device that may maintain synchronous uplink and downlink communications with a corresponding overhead satellite to minimize co-channel interference and maximize system capacity.

It is yet a further object of the invention to provide a router/formatter module which enables the use of dual use handsets capable of communicating directly with a satellite over a line of sight satellite communications link or with the router/formatter over an RF cellular link.

It is another object of the present invention to provide router/formatters capable of communicating directly with one another if located close enough to avoid a satellite link therebetween.

The above and other objects are achieved by the present invention which provides, in the preferred embodiment, a local telecommunications network for satellite based telecommunications. The network 10 includes multiple handsets 18-22, 50 and 54 which communicate directly with local ground stations 14 and 16. The local ground stations communicate with an overhead satellite 12 through a satellite telecommunications uplink. The satellite in turn communicates with a network ground station 41 to redirect the call to a secondary satellite and/or secondary local ground station. The local ground stations include routers for determining whether outgoing calls are directed to a destination handset located within or outside a predefined local geographic cell 30 and 32 for the corresponding local ground station 14 and 16. If the destination handset is located outside the local cell of the originating handset, the local ground station passes the call to the overhead satellite 12 and network ground station 41 to establish a satellite telecommunications link with a remote destination. However, if the destination handset 50 is located within the same local cell 32 as the originating handset 22, then the router establishes a link between the handsets 22 and 50 via the router-formatter 14 without establishing a satellite telecommunications link 26.

Brief Description of the Drawings

Fig. 1 illustrates a satellite based telecommunications system in block diagram form; and

Fig. 2 illustrates, in block diagram form, a router/formatter module according to the present invention.

Detailed Description of the Preferred Embodiment

Fig. 1 generally illustrates a satellite based telecommunications system 10. The system 10 includes a satellite 12 which communicates with local ground stations 14 and 16 located within the coverage area 28 afforded by antenna 34 of the satellite 12. The terms "ground" and "base" stations are used interchangeably throughout the application. The local ground station 14 directly communicates with mobile stations 18 and 20 located within the predefined cell 30 surrounding the

ground station 14. The cell 30 (denoted in dashed lines) may be of any desired predefined geographic shape. Optionally, the cell 30 may correspond to the maximum distance to which the ground station 14 is capable of transmitting. Local ground station 16 similarly communicates with mobile stations 22 located in the corresponding predefined cell 32. The local ground station 16 may also communicate with conventional telephones 50 and 54, which are connected to the local ground station 16 via local telephone line links 52 and 56.

The local ground stations 14 and 16 communicate via communications links 24 and 26, respectively, with the satellite 12. The communications links 24 and 26 represent bidirectional links for uplink and downlink communications. The local ground stations 14 and 16 include antennas 36 and 38, respectively, which maintain the communications links 24 and 26. The antennas 36 and 38 may represent "smart" or steerable antennas which may be capable of tracking the satellite 12. The antennas 36 and 38 may include phased arrays which may be capable of forming multiple steerable transmission beams adjusted to follow the orbital motion of the satellite 12. The antennas 36 and 38 may be configured to transmit at significantly higher power levels and employing a smaller beamwidth than those levels and beamwidths associated with conventional portable handsets used to directly communicate with telecommunications satellites. For instance, conventional portable handsets may utilize omni-directional antennas which operate at one-half watt of power. The antennas 36 and 38 may operate at significantly higher power levels, such as an order of magnitude or more greater than that used with omni-directional antennas in portable handsets.

In addition, the antennas 36 and 38 may be of any desired size (i.e. not limited to man-portable form factors). Preferably, the antennas 36 and 38 are positioned to afford an unobstructed line of sight with the satellite 12 throughout the satellite's overhead orbit (such as upon a rooftop building, in an open field, and the like). Optionally, by increasing the power level and size of the antennas 36 and 38 as compared with omni-directional antennas utilized with portable handsets, the local ground stations 14 and 16 are able to maintain the communications links 24 and 26 with high integrity and alleviate transmit power requirements on the satellite 12. Positioning the antennas 36 and 38 in an unobstructed area further assures fidelity of the communications links 24 and 26.

The local ground stations 14 and 16 include separate RF antennas 40 and 42 for communicating with the mobile stations 18-22. The RF antenna 40 maintains RF cellular links 44 and 46 with mobile stations 18 and 20, respectively. The RF antenna 42 maintains an RF cellular link 48 with mobile station 22.

The RF antennas 40 and 42 maintain the RF communications links 44-48 according to any conventional portable or cellular phone standard, such as the standard used in any of the following systems; namely, the

GSM system, the IS-95 system, the DECT system CT2, CT2+, AMPS, N-TDMA (IS-54), and the like. Hence, the mobile stations 18-22 need not maintain an unobstructed line of sight with the RF antennas 40 and 42.

The satellite 12 communicates with a network ground station 41 through a satellite link 43. The network ground station 41 may communicate with a PSTN 45 and remote telephones 47 that are connected to the PSTN 45. The satellite 12 relays all received calls to the network ground station 41 which determines a destination for the call. The network ground station 41 may direct the call to the PSTN 45, a second satellite or a second local or network ground station based on the call destination. Thus, a call may travel from handset 22 to local ground station 16, to satellite 12, to network ground station 41. The call may then be passed back to satellite 12 directly to handset 57, or to PSTN 45 or to local ground station 14.

Optionally the mobile stations may include an RF antenna and an omnidirectional satellite antenna and have dual operating modes. In a first mode, the mobile stations may communicate via RF links with corresponding local ground stations (as explained above). In a second mode, the mobile stations may communicate through the omni-directional antennas over a satellite communications link 29 directly with the satellite.

Optionally, the local ground stations may include third antennas 51 and 53 capable of directly communicating with one another over communications link 55. The local ground stations may communicate with any other local ground station located within a predefined geographic range and pass calls therebetween without use of the satellite.

The satellites may communicate directly with mobile stations, such as handset 57 via communications link 59 or handset 18 via communications link 29.

Fig. 2 illustrates a ground station 14 in more detail. The ground station 16 includes a router 60, a converter 62, and an antenna 38. The converter 62 includes a formatter 64 and a deformatter 66. The formatter 64 receives outgoing telecommunications calls on outgoing satellite line 72. The outgoing calls are formatted according to a local formatting standard which may be any of several conventional standards utilized in connection with portable and cellular phones, such as the standards used in the GSM system, IS-95 system, DECT system and the like. The formatter 64 converts the outgoing call to one of the formats corresponding to a conventional satellite telecommunications standard, such as that proposed in the Odyssey Iridium or GlobalStar systems. Optionally, the formatter 64 may process calls from multiple handsets and transmit the corresponding collective data stream in a synchronous manner with respect to time.

When the converter 62 effects synchronous operation, the formatter 64 may include a plurality of buffers, each of which separately receives outgoing call data from a corresponding local initiating handset. The locally initiated calls generally occur asynchronously.

The buffers in the formatter store the asynchronous outgoing call data. The stored call data is then combined, such as in a multiplexor and the like. The combined call data is transmitted synchronously after being time shifted (advanced or retarded) in the formatter 64. Once the formatter 64 completes the conversion of the outgoing signal, it transmits same along the uplink feed line 68 to the antenna 38. The antenna 38 transmits the outgoing call in a transmission beam to the satellite. When the converter 62 operates asynchronously, the buffers and additional circuitry for timing alignment may not be necessary.

The deformatter 66 receives incoming calls from the antenna 38 via down link receive line 70. The deformatter 66 converts the incoming calls to the local format and transmits these calls along the incoming local call line 74 to an incoming call controller 75. The incoming calls on line 74 are directed, via the controller 75, to the designated destination handset (handset 22 in the example of Fig. 2). The controller 75 may operate based on a satellite subscription method, whereby each mobile station has a unique satellite subscription ID. According to this subscription method, the controller 75 may include a database of local caller subscription IDs and their corresponding satellite IDs. (For Odyssey or GSM based systems, this is the temporary mobile station ID (TMSI)). When an incoming call is received, the controller obtains the TMSI for the destination handset from the call. The controller 75 may then use the TMSI as a local caller ID, or alternatively, obtain a separate corresponding local caller ID. The controller 75 then connects the incoming line 74 with the destination handset.

Alternately, the controller 75 may operate based on any of several conventions, including Direct Inward Dialing (DID), Direct Inward System Access (DISA), and the like. The controller 75 may also use an operator who manually routes incoming calls from a satellite to a local handset. DID gives outside callers the ability to call directly to a local handset with an extension number within the local cell. To do this, the outside caller would dial the handset code and a four-digit number, which would be the same as the person's local phone. The DID-type controller will require coordination with the network ground station. The network ground station must recognize the number as belonging to a router-formatter group. It then selects a temporary mobile satellite identifier TMSI that is assigned to the router-formatter group and is currently not in use. It then forwards the local caller subscription ID for the destination handset once the router-formatter has seized the call.

Direct inward system access (DISA) requires the network ground station to recognize the dialed number as belonging to a router-formatter group. It then selects a TMSI that is assigned to the router-formatter group that is currently not in use. Once the router-formatter has seized the call, the initialing handset will be prompted for the destination local caller ID.

With respect to outgoing calls, the router 60 func-

tions to establish a direct local link 86 between first and second local handsets (for instance 54 and 22) without establishing a satellite based remote link when the initiating and destination handsets 54 and 22 are both within the local cell corresponding to the ground station. However, when an initiating handset (50) designates a destination handset which is remote from the local cell, the router 60 establishes a satellite based remote link, via antenna 38, with the satellite and transmits the outgoing call from the local handset 50 to a remote destination handset (not shown in Fig. 2). The satellite based remote link refers to the communications link 26.

To effect routing, the router 60 includes a discriminator 78 and a switching network 76. The discriminator 78 is connected to all incoming lines from the local handsets. These incoming lines may represent hard wired lines 52 and 56. Alternatively, or in addition, the incoming lines may represent an RF cellular link 48 established between an RF antenna 42 and a remote handset 22. Upon receiving an incoming call from a handset, the discriminator 78 analyzes the call to determine whether the destination handset represents a local handset within the local cell 32 or represents a remote handset outside of the local cell 32. The discriminator 78 controls the switching network 76 based upon this determination. The user may dial "9" to inform the discriminator that an outside line is desired. Alternatively, the discriminator may include software to evaluate the number dialed. By way of example, when a handset 54 initiates a call directed to a local destination handset 22, the discriminator 78 controls the switching network 76 to establish a direct link 86 between the initiating and destination handsets 54 and 22 via switch 87. Alternatively, when the initiating handset 50 designates a remote destination handset, the discriminator 78 identifies the call as such and controls a switching network 76 to establish a satellite based remote link between the initiating handset 50 and the satellite 12 via lines 72 and 68, the antenna 38 and communications link 26 (Fig. 1).

The outgoing call is processed in a manner consistent with the selected incoming call embodiment. Namely, if all router-formatter handsets are satellite system subscribers, their specific subscription ID is used to enact satellite communication. If the DID or DISA method is used, wherein the router-formatter has fewer satellite subscriptions than total users, a subscription ID is assigned to the outgoing call based on availability.

According to the foregoing, the preferred embodiment is able to minimize traffic upon the satellite telecommunications links 24 and 26 by omitting therefrom calls strictly of a local nature. The preferred embodiment further enables the use of mobile stations 18-22 which communicate with a local ground station via RF cellular links, which are not limited to line of sight communications. In addition, the ground station 14 may use a high powered directional antenna 38, such as a phased array, which would enable tracking of an overhead satellite and maintain a communications link therewith of substantially better quality than achievable

by mobile portable handsets which communicate directly with the satellite. The use of a common antenna 38 for multiple channels may be used to gain the advantages of synchronizing the return link especially using orthogonal CDMA codes to minimize co-channel interference and thereby increasing the capacity of the communications link.

While particular elements, embodiments and applications of the present invention have been shown and described, it will be understood, of course, that the invention is not limited thereto since modifications may be made by those skilled in the art, particularly in light of the foregoing teachings. It is, therefore, contemplated by the appended claims to cover such modifications as incorporate those features which come within the spirit and scope of the invention.

Claims

1. A local telecommunications network for use in satellite based telecommunications, said network comprising:
first and second handsets for receiving and transmitting telecommunications signals, at least said first handset being located geographically in a predefined local cell; and a ground station, in said local cell, for controlling communications between said first and second handsets, said ground station relaying telecommunications signals between said first and second handsets through one of a direct link and a satellite based remote link, said ground station including:
a router for establishing said direct link between said first and second handsets, without establishing said satellite based remote link, when said first and second handsets are both located within said local cell, said router establishing said satellite based remote link between said first and second handsets when said second handset is located outside, and remote to, said local cell.
2. A local telecommunications network, according to claim 1, wherein said router includes a discriminator which receives out-going calls initiated by said first handset, said discriminator determining whether said outgoing calls are directed to a destination handset inside or outside of said local cell, said router establishing one of said direct link and satellite based remote link based on said determination by said discriminator, and/or wherein said router includes a switching network for connecting said first and second handsets through said direct link when said second handset represents a destination handset and when said second handset is

located in said local cell.

3. A local telecommunications network, according to claim 1, wherein said ground station further includes a formatter for converting an outgoing call from said first handset from a local format to a satellite telecommunications standard format, said formatter outputting said outgoing call in a synchronized manner with respect to time, and/or wherein said ground station further includes a deformatter for converting an incoming call to said first handset from a satellite telecommunications standard format to a local format.

4. A local telecommunications network, according to claim 1, wherein said ground station includes a transmitter for transmitting outgoing calls synchronously with respect to time.

5. A local telecommunications network, according to claim 1, wherein at least one of said first and second handsets communicates with said ground station through an RF cellular link or through a hard wired telephone line.

6. A local telecommunications network, according to claim 1, wherein said ground station further comprises an antenna for outputting a steerable transmission beam directed toward an overhead satellite to establish said satellite based remote link for carrying telecommunications from said first handset to a remote destination handset, and/or wherein said ground station further comprises a phased array antenna for maintaining said satellite based remote link with an overhead satellite for carrying said telecommunications signals to and from said local handset when said local handset communicates with a remote handset.

7. A local telecommunications network, according to claim 1, further comprising first and second ground stations which communicate with one another through said satellite based remote link and further comprising a third handset located in a second predefined geographic local cell surrounding said second ground station, said first and third handsets communicating through a said satellite based remote link between said first and second ground stations through an overhead satellite.

8. A local telecommunications network, according to claim 1, wherein said ground station further includes a formatter for converting an outgoing call from said first handset from a local format to a satellite telecommunications standard format, said formatter outputting said outgoing call in an asynchronous manner with respect to time.

9. A ground station for use in satellite based telecommunication between two handsets, at least one of said handsets being a local handset located in a predefined geographic local cell surrounding said ground station, said ground station comprising:

5 local communications links for outputting and receiving calls to and from local handsets; a discriminator, connected to said local communications links, for determining whether calls from a local initiating handset are directed to a destination handset which is located in said local cell; a router, including said discriminator, for directly connecting local initiating and local destination handsets through a direct link when said discriminator determines that said destination handset is local; and an antenna for establishing a satellite communications link between said ground station and an overhead satellite, said switching circuit connecting said local initiating handset to said antenna when said discriminator determines that said destination handset is remote from said local cell.

10. A ground station, according to claim 9, wherein said router comprises a switching network for connecting said local initiating handset to a local destination handset through said direct link when said discriminator determines that said destination handset is local.

11. A ground station, according to claim 9, further comprising a formatter for converting an outgoing call from said local initiating handset from a first format to a satellite telecommunications standard format, said formatter outputting said call in a synchronized manner with respect to time, and/or comprising a deformatter for converting an incoming call to a destination local handset from a satellite telecommunications standard format to a local format, and/or comprising a transmitter for transmitting outgoing calls synchronously with respect to time, and/or comprising an RF antenna for maintaining an RF cellular communications link with at least one local handset, and/or a ground station, according to claim 9, further comprising wired telephone lines for establishing a telephone link with at least one local handset.

12. A ground station, according to claim 9, wherein said antenna outputs a steerable satellite telecommunications beam adjustable to track an overhead satellite.

13. A ground station, according to claim 9, wherein said antenna constitutes a phased array antenna for outputting a satellite telecommunications beam for transmitting communications data to an overhead

satellite.

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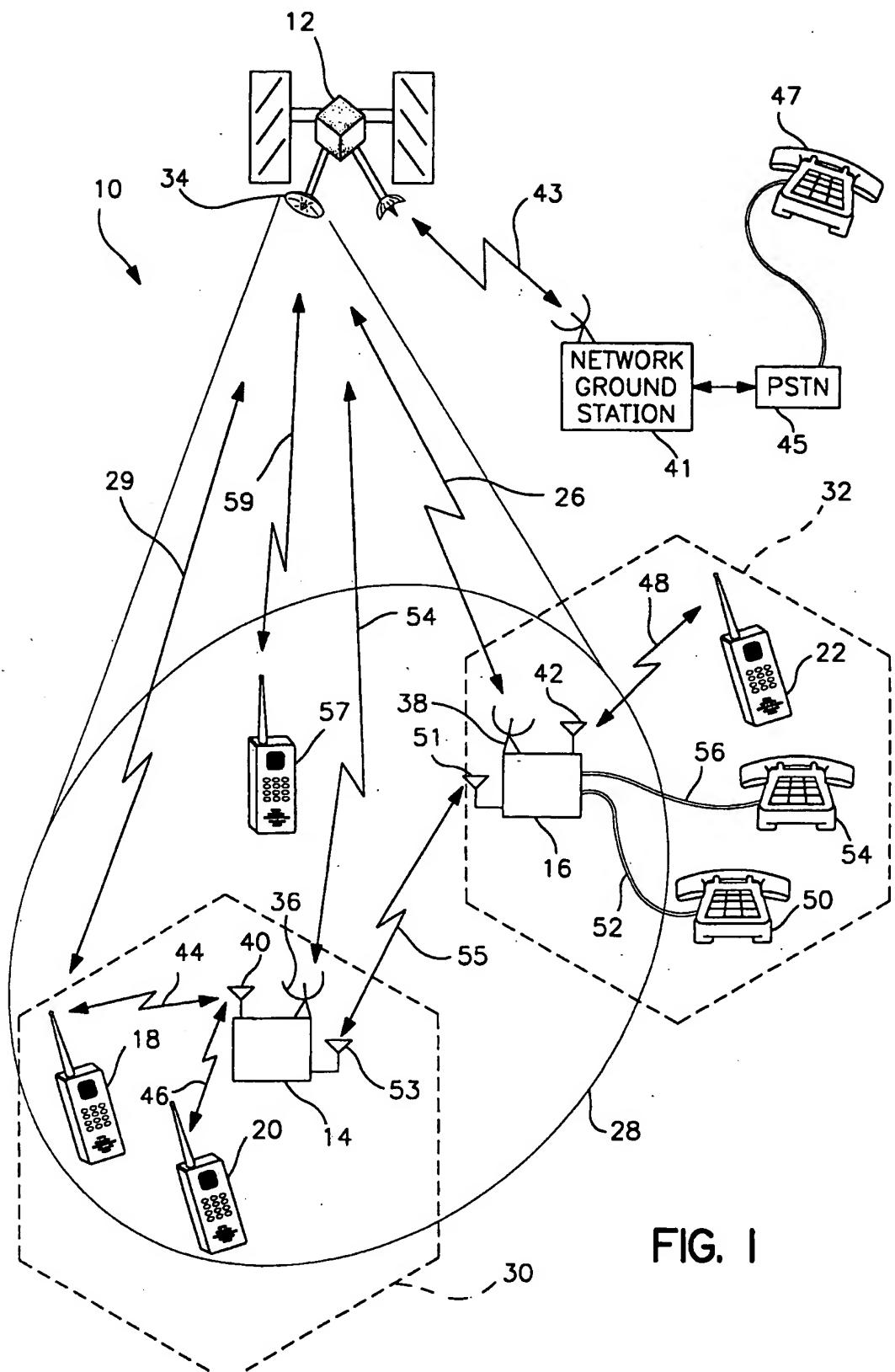


FIG. I

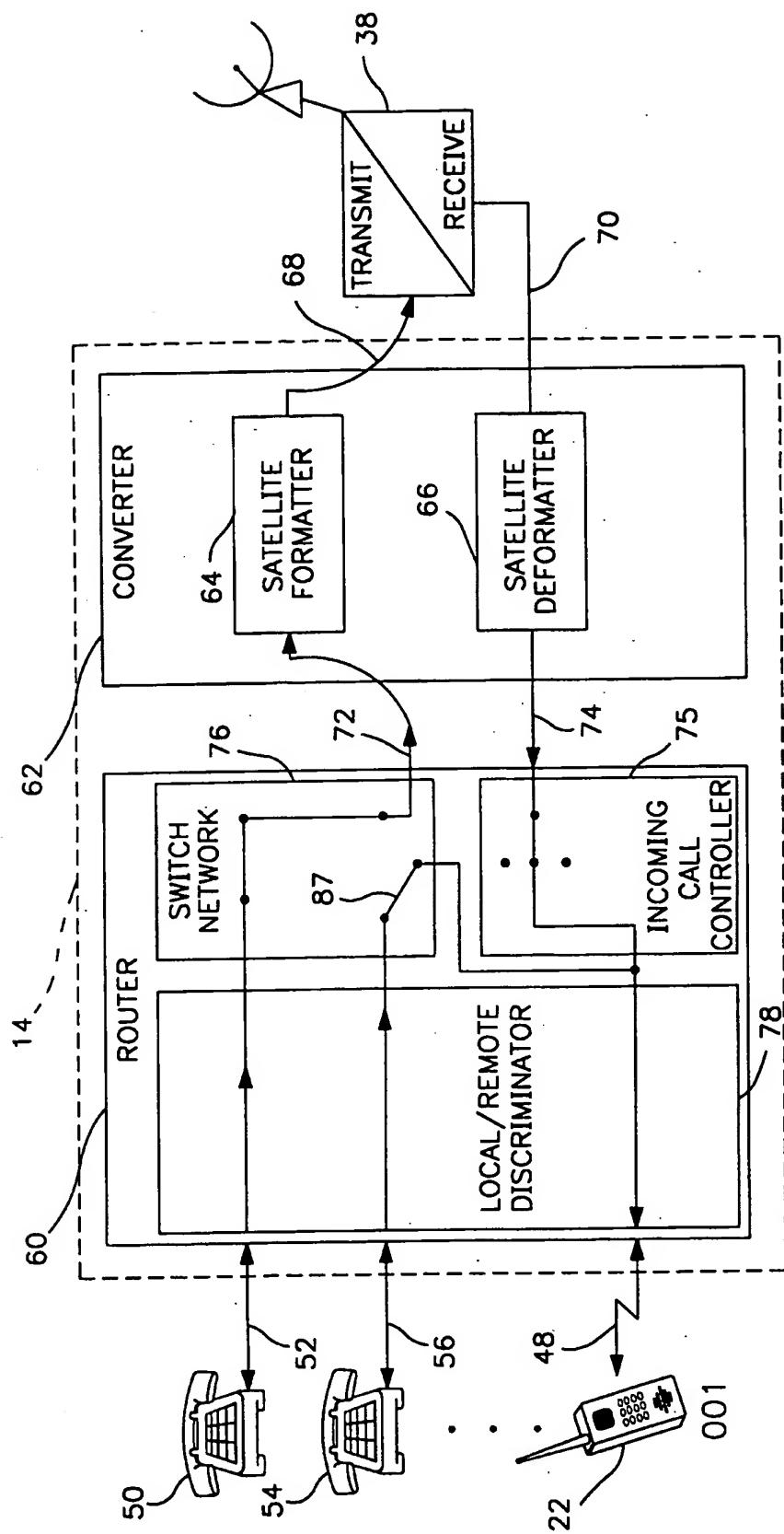


FIG. 2



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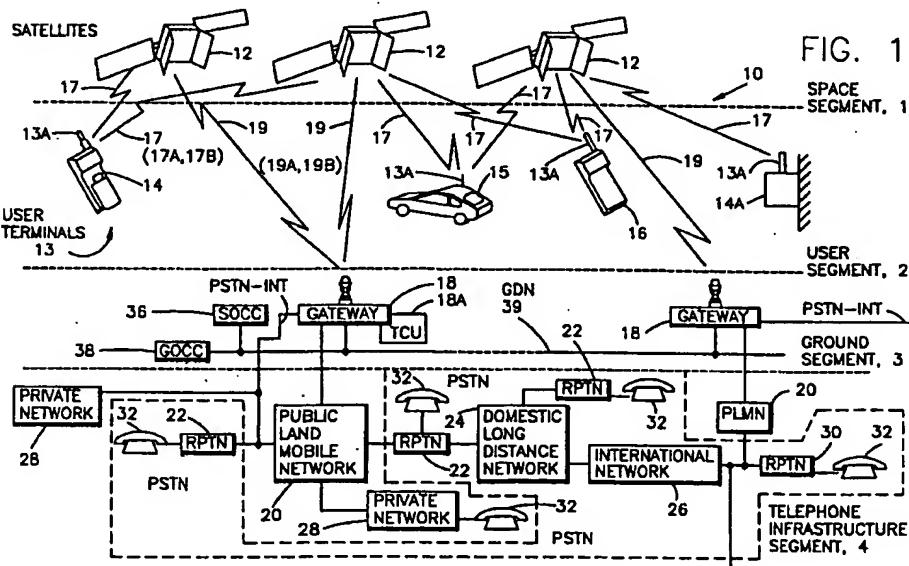
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(54) Satellite repeater diversity resource management system

(57) Methods and apparatus are disclosed for improving and optimizing the delivery of path diversity in a satellite repeater-based communication system, thereby conserving both FDM channels and satellite power utilization. The reception of communications is improved, when one or more orbiting satellite repeater (12) transmitters is blocked or severely faded, by recognizing the need for satellite path diversity on a real-time or near real-time basis. A user terminal (13) is thus enabled to receive sufficient signal strength to avoid having an ongoing call automatically terminated. The system

optimizes satellite path diversity applied to (a) classes (types) of user terminals and/or (b) to individual user terminals as a function of location and also a local RF propagation environment of the user terminal. In addition, the invention teaches a consideration of the satellite resources that are available at any given point in time, and may restrict or limit the availability of satellite path diversity, thereby increasing overall system capacity.



Description

This invention relates generally to satellite communication systems and, in particular, to satellite communication systems wherein satellites are employed as communication signal repeaters.

5 Signal blocking and fading in mobile communications systems is well known. Satellite-based systems generally have more stringent requirements than terrestrial-based systems due to the significantly longer propagation paths. In satellite mobile communications systems blocking and fading of user terminals by buildings, trees and terrain can be mitigated by using multiple orbiting satellite repeater transmitters to send multiple copies of a signal, via some or all satellite repeater transmitters in view, to a user which is potentially experiencing signal blocking and fading. These mitigation techniques, especially those using spread spectrum systems, utilize multiple signal path diversity (hereinafter referred to simply as "path diversity") as a means of maintaining communication paths when individual mobile users are in blocking and fading situations. Low Earth Orbit (LEO) satellite communication systems in particular can exploit path diversity since there are multiple satellites and, hence, multiple and different communication paths to and from the user.

10 Most known or proposed systems of this type, in addition to using Code Division Multiple Access (CDMA), generally channelize by frequency division multiplex (FDM). Furthermore, providing path diversity has an adverse effect of requiring the system to utilize many satellites. This increases the total power demand for each satellite, and also requires each satellite to make the same RF channels available for each user for path diversity transmissions. The end result can be a reduction in the total capacity of the system due to inefficiencies in RF channel assignment.

15 One approach to providing path diversity is to provide path diversity indiscriminately to all users. In fact, however, the inventor has realized that there are many different types of user terminals, as well as many different types of communication environments that a given user may reside in, either temporarily or permanently. For example, certain users will employ vehicle mounted terminals which can move through the environment rather quickly. Other users may employ hand-held or fixed terminals which may not be moving at all. In addition, there are a variety of terrains wherein users can be located, such as oceans, deserts, forests, suburban, urban, rural farmland, etc.

20 25 It can be appreciated that not all communication environments require the same level of path diversity, and furthermore not all user terminals within a given environment require the same level of path diversity.

The foregoing and other problems are overcome by a satellite communications system that is constructed and operated in accordance with this invention.

Methods and apparatus are disclosed for improving and optimizing the delivery of path diversity in a satellite 30 repeater-based communication system, thereby conserving both FDM channels and satellite power utilization. The reception of multiple signals is improved, when one or more orbiting satellite repeater (12) transmitters is blocked or severely faded, by recognizing the need for satellite path diversity on a real-time or near real-time basis. Thus, a user terminal (13) is enabled to receive sufficient signal strength to avoid having an ongoing communication automatically terminated by the optimization of path diversity (formed by multiple wireless links) that is applied to (a) classes (types) 35 of user terminals and/or (b) to individual user terminals as a function of location and also a local RF propagation environment of the user terminal. In addition, the invention teaches a consideration of the satellite resources that are available at any given point in time, and may restrict or limit the availability of satellite path diversity, thereby increasing overall system capacity.

Also, a particular user may be found to have a historical record or "signature" of operating within a certain environment. 40 The historical record can be utilized to optimize the user's typical usage, thereby further refining the potential for gaining higher system operating efficiency.

This invention teaches a method for operating a satellite communication system that includes the steps of (a) initiating a communication between a user terminal and a ground station via at least one satellite communication signal repeater; (b) classifying the user terminal as to type and/or determining a location of the user terminal within a service 45 coverage area of the ground station; and (c) selecting a number of satellite communication signal repeaters to relay the communication between the user terminal and the ground station, the selected number being a function of at least the type and/or location of the user terminal and other characteristics, which may be stored within a database. The step of selecting can include a step of determining an RF energy propagation characteristic that is associated with the determined location of the user terminal. The use of a service area RF propagation map is disclosed for this purpose, the 50 map being derived from, by example, satellite images of the natural and man-made features within the service area. The step of selecting can also include a step of considering a power control history of the user terminal. This is useful in distinguishing, by example, a mobile-type user terminal that is in motion from a mobile-type user terminal that happens to be stationary. The step of selecting may also include a step of considering a current availability of satellite communication signal RF channels within satellite repeaters and the physical circuit loading of the RF channels and satellite 55 repeaters.

In a presently preferred embodiment of this invention the communication is relayed as a spread spectrum, code division multiple access communication signal between the user terminal and the ground station. In this case the method includes the additional steps of (d) receiving the communication with the user terminal, wherein the communication is received through different communication paths associated with individual ones of the selected number of sat-

ellite communication signal repeaters; (e) equalizing at least the phase shifts and time delays of the received communication from each of the different paths to provide a plurality of equalized communication signals; and (f) combining the equalized communication signals into a composite received communication signal.

The above set forth and other features of the invention are made more apparent in the ensuing Detailed Description of the Invention when read in conjunction with the attached Drawings, wherein:

Fig. 1 is block diagram of a satellite communication system that is constructed and operated in accordance with a presently preferred embodiment of this invention;

10 Fig. 2 is a block diagram of one of the gateways of Fig. 1;

Fig. 3A is a block diagram of the communications payload of one of the satellites of Fig. 1;

15 Fig. 3B illustrates a portion of a beam pattern that is associated with one of the satellites of Fig. 1;

Fig. 4 is a block diagram that depicts the ground equipment support of satellite telemetry and control functions;

Fig. 5 is block diagram of the CDMA sub-system of Fig. 2;

20 Fig. 6 is block diagram of a forward link path diversity delivery system in accordance with this invention;

Fig. 7 is a block diagram of a portion of the path diversity delivery system of Fig. 6 in combination with a path diversity selection system in accordance with this invention;

25 Fig. 8 is a block diagram illustrating the reverse link from user terminal to gateway;

Fig. 9 is a block diagram of a path diversity return link embodiment of this invention;

30 Fig. 10 illustrates an exemplary communications environment map that is a feature of this invention; and

Fig. 11 is flow chart illustrating a method of this invention.

Fig. 1 illustrates a presently preferred embodiment of a satellite communication system 10 that is suitable for use with the presently preferred embodiment of this invention. Before describing this invention in detail, a description will first be made of the communication system 10 so that a more complete understanding may be had of the present invention.

The communications system 10 may be conceptually subdivided into a plurality of segments 1, 2, 3 and 4. Segment 1 is referred to herein as a space segment, segment 2 as a user segment, segment 3 as a ground (terrestrial) segment, and segment 4 as a telephone system infrastructure segment.

40 In the presently preferred embodiment of this invention there are a total of 48 satellites in, by example, a 1414 km Low Earth Orbit (LEO). The satellites 12 are distributed in eight orbital planes with six equally-spaced satellites per plane (Walker constellation). The orbital planes are inclined at 52 degrees with respect to the equator and each satellite completes an orbit once every 114 minutes. This approach provides approximately full-earth coverage with, preferably, at least two satellites in view at any given time from a particular user location between about 70 degree south latitude and about 70 degree north latitude. As such, a user is enabled to communicate to or from nearly any point on the earth's surface within a gateway (GW) 18 coverage area to or from other points on the earth's surface (by way of the PSTN), via one or more gateways 18 and one or more of the satellites 12, possibly also using a portion of the telephone infrastructure segment 4.

50 It is noted at this point that the foregoing and ensuing description of the system 10 represents but one suitable embodiment of a communication system within which the teaching of this invention may find use. That is, the specific details of the communication system are not to be read or construed in a limiting sense upon the practice of this invention.

Continuing now with a description of the system 10, a soft transfer (handoff) process between satellites 12, and also between individual ones of 16 spot beams transmitted by each satellite (Fig. 3B), provides unbroken communications via a spread spectrum (SS), code division multiple access (CDMA) technique. The presently preferred SS-CDMA technique is similar to the TIA/EIA Interim Standard, "Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System" TIA/EIA/IS-95, July 1993, although other spread spectrum and CDMA techniques and protocols can be employed.

The low earth orbits permit low-powered fixed or mobile user terminals 13 to communicate via the satellites 12,

each of which functions, in a presently preferred embodiment of this invention, solely as a "bent pipe" repeater to receive a communications traffic signal (such as speech and/or data) from a user terminal 13 or from a gateway 18, convert the received communications traffic signal to another frequency band, and to then re-transmit the converted signal. That is, no on-board signal processing of a received communications traffic signal occurs, and the satellite 12 does not become aware of any intelligence that a received or transmitted communications traffic signal may be conveying.

Furthermore, there need be no direct communication link or links between the satellites 12. That is, each of the satellites 12 receives a signal only from a transmitter located in the user segment 2 or from a transmitter located in the ground segment 3, and transmits a signal only to a receiver located in the user segment 2 or to a receiver located in the ground segment 3.

10 The user segment 2 may include a plurality of types of user terminals 13 that are adapted for communication with the satellites 12. The user terminals 13 include, by example, a plurality of different types of fixed and mobile user terminals including, but not limited to, handheld mobile radio-telephones 14, vehicle mounted mobile radio-telephones 15, paging/messaging-type devices 16, and fixed radio-telephones 14a. The user terminals 13 are preferably provided with omnidirectional antennas 13a for bidirectional communication via one or more of the satellites 12.

15 It is noted that the fixed radio-telephones 14a may employ a directional antenna. This is advantageous in that it enables a reduction in interference with a consequent increase in the number of users that can be simultaneously serviced with one or more of the satellites 12.

It is further noted that the user terminals 13 may be dual use devices that include circuitry for also communicating in a conventional manner with a terrestrial cellular system.

20 Referring also to Fig. 3A, the user terminals 13 may be capable of operating in a full duplex mode and communicate via, by example, L-band RF links (uplink or return link 17b) and S-band RF links (downlink or forward link 17a) through return and forward satellite transponders 12a and 12b, respectively. The return L band RF links 17b may operate within a frequency range of 1.61 GHz to 1.625 GHz, a bandwidth of 16.5 MHz, and are modulated with packetized digital voice signals and/or data signals in accordance with the preferred spread spectrum technique. The forward S band RF links 25 17a may operate within a frequency range of 2.485 GHz to 2.5 GHz, a bandwidth of 16.5 MHz. The forward RF links 17a are also modulated at a gateway 18 with packetized digital voice signals and/or data signals in accordance with the spread spectrum technique.

The 16.5 MHz bandwidth of the forward link is partitioned into 13 channels with up to, by example, 128 users being assigned per channel. The return link may have various bandwidths, and a given user terminal 13 may or may not be 30 assigned a different channel than the channel assigned on the forward link. However, when operating in the diversity reception mode on the return link (receiving from two or more satellites 12), the user is assigned the same forward and return link RF channel for each of the satellites.

35 The ground segment 3 includes at least one but generally a plurality of the gateways 18 that communicate with the satellites 12 via, by example, a full duplex C band RF link 19 (forward link 19a (to the satellite), return link 19b (from the satellite)) that operates within a range of frequencies generally above 3 GHz and preferably in the C-band. The C-band RF links bi-directionally convey the communication feeder links, and also convey satellite commands to the satellites and telemetry information from the satellites. The forward feeder link 19a may operate in the band of 5 GHz to 5.25 GHz, while the return feeder link 19b may operate in the band of 6.875 GHz to 7.075 GHz.

40 The satellite feeder link antennas 12g and 12h are preferably wide coverage antennas that subtend a maximum earth coverage area as seen from the LEO satellite 12. In the presently preferred embodiment of the communication system 10 the angle subtended from a given LEO satellite 12 (assuming 10° elevation angles from the earth's surface) is approximately 110°. This yields a coverage zone that is approximately 3600 miles in diameter.

45 The L-band and the S-band antennas are multiple beam antennas that provide coverage within an associated terrestrial service region. The L-band and S-band antennas 12d and 12c, respectively, are preferably congruent with one another, as depicted in Fig. 3B. That is, the transmit and receive beams from the spacecraft cover the same area on the earth's surface, although this feature is not critical to the operation of the system 10.

50 As an example, several thousand full duplex communications may occur through a given one of the satellites 12. In accordance with a feature of the system 10, two or more satellites 12 may each convey the same communication between a given user terminal 13 and one of the gateways 18. This mode of operation, as described in detail below, thus provides for diversity combining at the respective receivers, leading to an increased resistance to fading and facilitating the implementation of a soft handoff procedure.

55 It is pointed out that all of the frequencies, bandwidths and the like that are described herein are representative of but one particular system. Other frequencies and bands of frequencies may be used with no change in the principles being discussed. As but one example, the feeder links between the gateways and the satellites may use frequencies in a band other than the C-band (approximately 3 GHz to approximately 7 GHz), for example the Ku band (approximately 10 GHz to approximately 15 GHz) or the Ka band (above approximately 15 GHz).

The gateways 18 function to couple the communications payload or transponders 12a and 12b (Fig. 3A) of the satellites 12 to the telephone infrastructure segment 4. The transponders 12a and 12b include an L-band receive antenna 12c, S-band transmit antenna 12d, C-band power amplifier 12e, C-band low noise amplifier 12f, C-band antennas 12g

and 12h, L band to C band frequency conversion section 12i, and C band to S band frequency conversion section 12j. The satellite 12 also includes a master frequency generator 12k and command and telemetry equipment 12l.

Reference in this regard may also be had to U.S. Patent No. _____, by E. Hirshfield and C.A. Tsao, entitled "Mobile Communications Satellite Payload" (S.N. 08/060,207).

5 The telephone infrastructure segment 4 is comprised of existing telephone systems and includes Public Land Mobile Network (PLMN) gateways 20, local telephone exchanges such as regional public telephone networks (RPTN) 22 or other local telephone service providers, domestic long distance networks 24, international networks 26, private networks 28 and other RPTNs 30. The communication system 10 operates to provide bidirectional voice and/or data communication between the user segment 2 and Public Switched Telephone Network (PSTN) telephones 32 and non-
10 PSTN telephones 32 of the telephone infrastructure segment 4, or other user terminals of various types, which may be private networks.

Also shown in Fig. 1 (and also in Fig. 4), as a portion of the ground segment 3, is a Satellite Operations Control Center (SOCC) 36, and a Ground Operations Control Center (GOCC) 38. A communication path, which includes a Ground Data Network (GDN) 39 (see Fig. 2), is provided for interconnecting the gateways 18 and TCUs 18a, SOCC 36 and GOCC 38 of the ground segment 3. This portion of the communications system 10 provides overall system control functions.

15 Fig. 2 shows one of the gateways 18 in greater detail. Each gateway 18 includes up to four dual polarization RF C-band sub-systems each comprising a dish antenna 40, antenna driver 42 and pedestal 42a, low noise receivers 44, and high power amplifiers 46. All of these components may be located within a radome structure to provide environmental protection.

20 The gateway 18 further includes down converters 48 and up converters 50 for processing the received and transmitted RF carrier signals, respectively. The down converters 48 and the up converters 50 are connected to a CDMA sub-system 52 which, in turn, is coupled to the Public Switched Telephone Network (PSTN) through a PSTN interface 54. As an option, the PSTN could be bypassed by using satellite-to-satellite links.

25 The CDMA sub-system 52 includes a signal summer/switch unit 52a, a Gateway Transceiver Subsystem (GTS) 52b, a GTS Controller 52c, a CDMA Interconnect Subsystem (CIS) 52d, and a Selector Bank Subsystem (SBS) 52e. The CDMA sub-system 52 is controlled by a Base Station Manager (BSM) 52f and functions in a manner similar to a CDMA-compatible (for example, an IS-95 compatible) base station. The CDMA sub-system 52 also includes the required frequency synthesizer 52g and a Global Positioning system (GPS) receiver 52h.

30 The PSTN interface 54 includes a PSTN Service Switch Point (SSP) 54a, a Call Control Processor (CCP) 54b, a Visitor Location Register (VLR) 54c, and a protocol interface 54d to a Home Location Register (HLR). The HLR may be located in the cellular gateway 20 (Fig. 1) or, optionally, in the PSTN interface 54.

35 The gateway 18 is connected to telecommunication networks through a standard interface made through the SSP 54a. The gateway 18 provides an interface, and connects to the PSTN via Primary Rate Interface (PRI). The gateway 18 is further capable of providing a direct connection to a Mobile Switching Center (MSC).

The gateway 18 provides SS-7 ISDN fixed signalling to the CCP 54b. On the gateway-side of this interface, the CCP 54b interfaces with the CIS 52d and hence to the CDMA sub-system 52. The CCP 54b provides protocol translation functions for the system Air Interface (AI), which may be similar to the IS-95 Interim Standard for CDMA communications.

40 Blocks 54c and 54d generally provide an interface between the gateway 18 and an external cellular telephone network that is compatible, for example, with the IS-41 (North American Standard, AMPS) or the GSM (European Standard, MAP) cellular systems and, in particular, to the specified methods for handling roammers, that is, users who place calls outside of their home system. The gateway 18 supports user terminal authentication for system 10/AMPS phones and for system 10/GSM phones. In service areas where there is no existing telecommunications infrastructure, an HLR can be added to the gateway 18 and interfaced with the SS-7 signalling interface.

45 A user making a call out of the user's normal service area (a roamer) is accommodated by the system 10 if authorized. In that a roamer may be found in any environment, a user may employ the same terminal equipment to make a call from anywhere in the world, and the necessary protocol conversions are made transparently by the gateway 18. The protocol interface 54d is bypassed when not required to convert, by example, GSM to AMPS.

50 It is within the scope of the teaching of this invention to provide a dedicated, universal interface to the cellular gateways 20, in addition to or in place of the conventional "A" interface specified for GSM mobile switching centers and vendor-proprietary interfaces to IS-41 mobile switching centers. It is further within the scope of this invention to provide an interface directly to the PSTN, as indicated in Fig. 1 as the signal path designated PSTN-INT.

55 Overall gateway control is provided by the gateway controller 56 which includes an interface 56a to the above-mentioned Ground Data Network (GDN) 39 and an interface 56b to a Service Provider Control Center (SPCC) 60. The gateway controller 56 is generally interconnected to the gateway 18 through the BSM 52f and through RF controllers 43 associated with each of the antennas 40. The gateway controller 56 is further coupled to a database 62, such as a database of users, satellite ephemeris data, etc., and to an I/O unit 64 that enables service personnel to gain access to the gateway controller 56. The GDN 39 is also bidirectionally interfaced to a Telemetry and Command (T&C) unit 66 (Figs.

1 and 4).

Referring to Fig. 4, the function of the GOCC 38 is to plan and control satellite utilization by the gateways 18, and to coordinate this utilization with the SOCC 36. In general, the GOCC 38 analyses trends, generates traffic plans, allocates satellite 12 and system resources (such as, but not limited to, power and channel allocations), monitors the performance of the overall system 10, and issues utilization instructions, via the GDN 39, to the gateways 18 in real time or in advance.

The SOCC 36 operates to maintain and monitor orbits, to relay satellite usage information to the gateway for input to the GOCC 38 via the GDN 39, to monitor the overall functioning of each satellite 12, including the state of the satellite batteries, to set the gain for the RF signal paths within the satellite 12, to ensure optimum satellite orientation with respect to the surface of the earth, in addition to other functions.

As described above, each gateway 18 functions to connect a given user to the PSTN for both signalling, voice and/or data communications and also to generate data, via database 62 (Fig. 2), for billing purposes. Selected gateways 18 include a Telemetry and Command Unit (TCU) 18a for receiving telemetry data that is transmitted by the satellites 12 over the return link 19b and for transmitting commands up to the satellites 12 via the forward link 19a. The GDN 39 operates to interconnect the gateways 18, GOCC 38 and the SOCC 36.

In general, each satellite 12 of the LEO constellation operates to relay information from the gateways 18 to the users (C band forward link 19a to S band forward link 17a), and to relay information from the users to the gateways 18 (L band return link 17b to C band return link 19b). This information includes SS-CDMA synchronization and paging channels, in addition to power control signals. Various CDMA pilot channels may also be used to monitor interference on the forward link. Satellite ephemeris update data is also communicated to each of the user terminals 13, from the gateway 18, via the satellites 12.

The satellites 12 also function to relay signalling information from the user terminals 13 to the gateway 18, including access requests, power change requests, and registration requests. The satellites 12 also relay communication signals between the users and the gateways 18, and may apply security to mitigate unauthorized use.

In operation, the satellites 12 transmit spacecraft telemetry data that includes measurements of satellite operational status. The telemetry stream from the satellites, the commands from the SOCC 36, and the communications feeder links 19 all share the C band antennas 12g and 12h. For those gateways 18 that include a TCU 18a the received satellite telemetry data may be forwarded immediately to the SOCC 36, or the telemetry data may be stored and subsequently forwarded to the SOCC 36 at a later time, typically upon SOCC request. The telemetry data, whether transmitted immediately or stored and subsequently forwarded, is sent over the GDN 39 as packet messages, each packet message containing a single minor telemetry frame. Should more than one SOCC 36 be providing satellite support, the telemetry data is routed to all of the SOCCs.

The SOCC 36 has several interface functions with the GOCC 38. One interface function is orbit position information, wherein the SOCC 36 provides orbital information to the GOCC 38 such that each gateway 18 can accurately track up to four satellites that may be in view of the gateway. This data includes data tables that are sufficient to allow the gateways 18 to develop their own satellite contact lists, using known algorithms. The SOCC 36 is not required to know the gateway tracking schedules. The TCU 18a searches the downlink telemetry band and uniquely identifies the satellite being tracked by each antenna prior to the propagation of commands.

Another interface function is satellite status information that is reported from the SOCC 36 to the GOCC 38. The satellite status information includes both satellite/transponder availability, battery status and orbital information and incorporates, in general, any satellite-related limitations that would preclude the use of all or a portion of a satellite 12 for communications purposes.

An important aspect of the system 10 is the use of SS-CDMA in conjunction with diversity combining at the gateway receivers and at the user terminal receivers. Diversity combining is employed to mitigate the effects of fading as signals arrive at the user terminals 13 or the gateway 18 from multiple satellites over multiple and different path lengths. Rake receivers in the user terminals 13 and the gateways 18 are employed to receive and combine the signals from multiple sources. As an example, a user terminal 13 or the gateway 18 provides diversity combining for the forward link signals or the return link signals that are simultaneously received from and transmitted through the multiple beams of the satellites 12.

In this regard the disclosure of U.S. Patent No. 5,233,626, issued August 3, 1993 to Stephen A. Ames and entitled "Repeater Diversity Spread Spectrum Communication System", is incorporated by reference herein in its entirety.

The performance in the continuous diversity reception mode is superior to that of receiving one signal through one satellite repeater, and furthermore there is no break in communications should one link be lost due to shadowing or blockage from trees or other obstructions that have an adverse impact on the received signal.

The multiple, directional, antennas 40 of a given one of the gateways 18 are capable of transmitting the forward link signal (gateway to user terminal) through different beams of one or more satellites 12 to support diversity combining in the user terminals 13. The omnidirectional antennas 13a of the user terminals 13 transmit through all satellite beams that can be "seen" from the user terminal 13.

Each gateway 18 supports a transmitter power control function to address slow fades, and also supports block

interleaving to address medium to fast fades. Power control is implemented on both the forward and reverse links. The response time of the power control function is adjusted to accommodate for a worst case 30 msec satellite round trip delay.

5 The block interleavers (53d, 53e, 53f, Fig. 5) operate over a block length that is related to vocoder 53g packet frames. An optimum interleaver length trades off a longer length, and hence improved error correction, at the expense of increasing the overall end-to-end delay. A preferred maximum end-to-end delay is 150 msec or less. This delay includes all delays including those due to the received signal alignment performed by the diversity combiners, vocoder 53g processing delays, block interleaver 53d-53f delays, and the delays of the Viterbi decoders (not shown) that form a portion of the CDMA sub-system 52.

10 Fig. 5 is a block diagram of the forward link modulation portion of the CDMA sub-system 52 of Fig. 2. An output of a summer block 53a feeds a frequency agile up-converter 53b which in turn feeds the summer and switch block 52a. The telemetry and control (T&C) information is also input to the block 52a.

15 An unmodulated direct sequence SS pilot channel generates an all zeros Walsh Code at a desired bit rate. This data stream is combined with a short PN code that is used to separate signals from different gateways 18 and different satellites 12. If used, the pilot channel is modulo 2 added to the short code and is then QPSK or BPSK spread across the CDMA FD RF channel bandwidth. The following different pseudonoise (PN) code offsets are provided: (a) a PN code offset to allow a user terminal 13 to uniquely identify a gateway 18; (b) a PN code offset to allow the user terminal 13 to uniquely identify a satellite 12; and (C) a PN code offset to allow the user terminal 13 to uniquely identify a given one of the 16 beams that is transmitted from the satellite 12. Pilot PN codes from different ones of the satellites 12 are 20 assigned different time/phase offsets from the same pilot seed PN code.

25 If used, each pilot channel that is transmitted by the gateway 18 may be transmitted at a higher or lower power level than the other signals. A pilot channel enables a user terminal 13 to acquire the timing of the forward CDMA channel, provides a phase reference for coherent demodulation, and provides a mechanism to perform signal strength comparisons to determine when to initiate handoff. The use of the pilot channel is not, however, mandatory, and other techniques can be employed for this purpose.

30 The Sync channel generates a data stream that includes the following information: (a) time of day; (b) transmitting gateway identification; (c) satellite ephemeris; and (d) assigned paging channel. The Sync data is applied to a convolutional encoder 53h where the data is convolutionally encoded and subsequently block interleaved to combat fast fades. The resulting data stream is modulo two added to the synchronous Walsh code and QPSK or BPSK spread across the 35 CDMA FD RF channel bandwidth.

35 The Paging channel is applied to a convolutional encoder 53i where it is convolutionally encoded and is then block interleaved. The resulting data stream is combined with the output of a long code generator 53j. The long PN code is used to separate different user terminal 13 bands. The paging channel and the long code are modulo two added and provided to a symbol cover where the resulting signal is modulo two added to the Walsh Code. The result is then QPSK or BPSK spread across the CDMA FD RF channel bandwidth.

40 In general, the paging channel conveys several message types which include: (a) a system parameter message; (b) an access parameter message; and (c) a CDMA channel list message.

45 The system parameter message includes the configuration of the paging channel, registration parameters, and parameters to aid in acquisition. The access parameters message includes the configuration of the access channel and the access channel data rate. The CDMA channel list message conveys, if used, an associated pilot identification and Walsh code assignment.

50 The vocoder 53k encodes the voice into a PCM forward traffic data stream. The forward traffic data stream is applied to a convolutional encoder 53l where it is convolutionally encoded and then block interleaved in block 53f. The resulting data stream is combined with the output of a user long code block 53k. The user long code is employed to separate different subscriber channels. The resulting data stream is then power controlled in multiplexer (MUX) 53m, modulo two added to the Walsh code, and then QPSK or BPSK spread across the CDMA FD RF communication channel bandwidth.

55 The gateway 18 operates to demodulate the CDMA return link(s). There are two different codes for the return link: (a) the zero offset code; and (b) the long code. These are used by the two different types of return link CDMA Channels, namely the access channel and the return traffic channel.

For the access channel the gateway 18 receives and decodes a burst on the access channel that requests access. The access channel message is embodied in a long preamble followed by a relatively small amount of data. The preamble is the user terminal's long PN code. Each user terminal 13 has a unique long PN code generated by a unique time offset into the common PN generator polynomial.

55 After receiving the access request, the gateway 18 sends a message on the forward link paging channel (blocks 53e, 53i, 53j) acknowledging receipt of the access request and assigning a Walsh code to the user terminal 13 to establish a traffic channel. The gateway 18 also assigns a frequency channel to the user terminal 13. Both the user terminal 13 and the gateway 18 switch to the assigned channel element and begin duplex communications using the assigned Walsh (spreading) code(s).

The return traffic channel is generated in the user terminal 13 by convolutionally encoding the digital data from the local data source or the user terminal vocoder. The data is then block interleaved at predetermined intervals and is applied to a 128-Ary modulator and a data burst randomizer to reduce clashing. The data is then added to the zero offset PN code and transmitted through one or more of the satellites 12 to the gateway 18.

5 The gateway 18 processes the return link by using, by example, a Fast Hadamard Transform (FHT) to demodulate the 128-Ary Walsh Code and provide the demodulated information to the diversity combiner.

The foregoing has been a description of a presently preferred embodiment of the communication system 10. A description is now made of presently preferred embodiments of the present invention.

10 The foregoing has been a description of a presently preferred embodiment of the communication system 10. A description is now made of presently preferred embodiments of this invention.

This invention builds upon the invention disclosed in the above-referenced U.S. Patent 5,223,626 to Stephen Ames which is entitled "Repeater Diversity Spread Spectrum Communications System".

15 In the system described in the Ames patent multiple signals can be concurrently transmitted from multiple independent transmitters and antennas to a single user receiver via multiple satellite repeaters, thus forming multiple forward paths 19a, 17a from a gateway 18 to the user terminal 13. The return paths are likewise defined from the single user terminal 13 to multiple independent gateway antennas and receivers via multiple satellite repeaters.

20 In the present invention, the transmission of the signals from the multiple independent transmitters and antennas are optimized and selected under the control of the gateway 18, in accordance with information provided by or for the user terminal being served, and also information stored in the gateway 18. The selection of one or more satellite repeaters is based on this information.

The teaching of this invention is primarily directed to the forward link 19a, 17a; i.e., the direction from the gateway 18 to a user terminal 13 via one or more of the satellite repeaters 12. However, the teaching of this invention is also applicable to the return link path 17b, 19b, if directional antenna means are available for the user terminal 13. Both of these embodiments (i.e., forward link and reverse link) are described in detail below.

25 Referring now to Fig. 6, there is shown a Path Diversity Delivery System 60 in accordance with this invention. The gateway frequency determination unit 43 sends a single input of traffic signals to one or more of several independent paths and forwards these to one or more transmitters 46a, 46b, 46c which amplifies each signal on the same frequency and delivers the amplified signal to one or more corresponding gateway directional antennas 40a, 40b, 40c for transmission, simultaneously or essentially simultaneously and with the same RF channel frequency, to the satellite repeaters 12. However, with proper signal processing and combining in the user terminal 13 there may be arbitrary delays in transmission. The receive antennas 12h of the selected satellite repeaters receive the uplink (forward path 19a) signals (not necessarily simultaneously) and transmit the signals to the ground via antennas 12d. Although three satellites are depicted as being involved in the transmission of the communication to the user terminal 13, it should be realized that from one to n satellite repeaters 12 can be used, where n is equal to or greater than two.

35 The selected one or more transmitted signals are received at the user terminal antenna 13a and sent to the receiver for diversity combining. The receiver of the user terminal 13 can be constructed and operated in the manner described in the above-referenced Ames patent, which has been incorporated by reference herein. It is within the scope of this invention to also employ other diversity combining techniques.

40 Fig. 7 illustrates a portion of the Path Diversity Delivery System 60 of Fig. 6 and also a Path Diversity Selection System (PDSS) 70 which is constructed and operated in accordance with this invention.

The PDSS 70 receives inputs from external information sources, including a User Terminal Position Location 72, User Power Activity 74, and a User Terminal Type 76. User historical system use data 77 is collected and organized by a user historical database system 95 and stored in a database 86. The historical system use data 77 can, by example, include an environment within which the user terminal 13 is most often used (e.g., urban area, rural area), and can also include a typical or average length of time that the user terminal is employed for making a call or connection. The gateway 18 has access to such information in that it is primarily responsible for managing individual user connections and for gathering billing-related information for individual user terminals.

45 The PDSS 70 includes a transmitter control unit 78 which issues control instructions 78a to the frequency determination unit 43 of the Path Diversity Delivery System 60. The control instructions 78a specify which transmitter and antenna pair (46a, 40a, etc) to use in directing user traffic signals 62 over specified forward links 19a to selected one of the satellite repeaters 12. The transmitter control unit 78 receives instructions from an instruction interface 80 which is connected to a computing subsystem 82. The computing subsystem 82 determines the number of diversity paths that should be provided, and the type of diversity. The type of diversity may include which satellite repeater or repeaters should be used. The computing subsystem 82 can also determine other control parameters, such as power levels to transmit. The computing subsystem 82 operates according to a rules set or algorithm set 84. The computing subsystem 82 receives inputs from and operates on (a) information stored in the database 86, (b) information provided from a satellite loading and resources availability subsystem 88, (c) the position of the user as provided by a position location subsystem 90, (d) historical system usage by the user, and (e) other sources of user information which may be used to determine a need or lack of need for path diversity. The location of the user terminal 13 is referenced to a service area

propagation map 92, also referred to herein as a communications environment map, which may also be stored in the database 86.

The computing subsystem 82, acting on the output of the user terminal position location subsystem 90 and on the data from the service area propagation map 92 which is stored in the database 86, is enabled to determine an environment of the user terminal 13. This user terminal environment information is employed for further processing and decision making with regard to path diversity selection. The user terminal power utilization 74 may be monitored and/or measured by a user activity subsystem 94, and provided to the computing subsystem 82 through the database 86 as described below.

The instruction interface 80 also provides instructions to a return link control unit 96, which in turn provides instructions 96a to a user terminal frequency control unit 64 which forms a part of the Path Diversity Delivery System 60.

In operation, a user terminal 13 logs into the communications system 10 and is assigned to a service area which is under the control of a gateway 18 having the antennas 40a-40c and transmitters 46a-46c that are establishing the diversity of the traffic signals with the user. At log in and/or at other specified times, including at call setup time, a user terminal type is transmitted to the gateway 18 along with the Electronic Serial Number (ESN) of the user terminal 13.

The user terminal type information can be transmitted at each telephone call, or the user terminal type information can be stored in, by example, a user information database, in a home location register (HLR), or in a visitor location register (VLR) that is in the gateway 18 or in a terrestrial network that the gateway 18 is connected to. In any case the user terminal type information can be detected and communicated by some means to database information 86. As a result, the user terminal type is known to the gateway 18. For example, and referring again to Fig. 1, there may be vehicle mounted voice terminals 15, hand-held voice terminals 14, hand-held data terminals, paging and messaging hand-held terminals 16, fixed user terminals 14a, or any number of other types of user terminals.

Each of these types of user terminals may have different diversity requirements. For example, a vehicle mounted user terminal 15 which is moving at high speed in a forested area may require diversity from three of the satellites 12 to assure continuity of service, while a hand-held user terminal 14 which is located on a pleasure boat on a lake, or in an open desert area, may not require any diversity.

Since the types of user terminals 13 are known to the gateway 18, diversity can be determined and applied as a group to all terminals of the same type. Alternatively and in a more complex manner, the computing subsystem 82 can dynamically assign diversity to users accessing the satellite system 10 with differing types of user terminals, by issuing instructions to the transmitter control 78 unit via the instruction interface 80.

Further refinements of diversity control may be exercised within each user terminal type group if knowledge is had of the type of terrain within which the user terminal 13 is located. In order to determine the type of terrain that the user is located in it may be necessary to know the location of the user terminal and the environmental characteristics of the user's location.

The user terminal location can be determined in several ways. By example, the user terminal 13 can send to the system 10 the location information by way of an operator-entered code (e.g., 01=urban, 02=rural, 03=water, etc.). Also by example, the user terminal location can be output from a position location subsystem 90, such as GPS, LORAN or some other device which calculates the user's location. Also by example, the system can locate the user terminal by ranging or triangulation using signals from the constellation of satellites 12.

In any case, the user terminal location is assumed to be known to the position location subsystem 90. The user terminal location information, combined with service area propagation map 92 information stored in the database 86, is operated on by the computing subsystem 82 to determine and select the amount or degree of path diversity for a given user terminal. For example, a vehicle mounted terminal 15 traveling in a forested area may need three satellite diversity (as shown in Fig. 6), while the same vehicle mounted terminal 15 traveling in open country such as plains or a desert may be able to achieve the same level of service quality with only one satellite 12 (i.e., no diversity at all). Likewise, a hand-held terminal 14 located in an urban area may require three satellite diversity, while the same type of terminal located on a lake or ocean may require only one satellite 12 to obtain the same connection quality.

The service area propagation map 92 (see, for example, Fig. 10) that is stored in the database 86 can be implemented in various ways, such as with a geographic database. Alternatively, satellite images of the gateway coverage area can determine regions of terrain features based on reflectivity values. Furthermore, it is known that satellite images taken in different spectral bands can be used to locate and identify regions having certain types of vegetation, such as forests. Such images can also be included within the database 86. In this regard seasonal variations in vegetation cover can also be factored into the diversity determination method. By example, a user terminal located within a region identified as having a deciduous forest can be assigned three satellite diversity during the summer months, to compensate for attenuation due to leaves, while the same user terminal in the same forested region in the winter months may be assigned only two satellite diversity.

It is also within the scope of the invention to employ real-time or substantially real-time weather information, such as that provided by Doppler radar, in determining diversity for a given user terminal. By example, and depending upon the RF frequencies in use, user terminals that are known to be located within rain cells within the gateway 18 coverage area, as determined from Doppler radar images of the gateway 18 coverage area, may have their diversity level

increased over those terminals not currently located within a rain cell.

In general, known types of computer techniques are employed to develop detailed environmental maps that include vegetation, natural terrain features, suburban and urban development, as well as roads, farmland, industrial areas, and other man-made objects. These image maps, when combined with other database information, such as the user terminal type, provide detailed information on the terminal's environment of reception and/or transmission. The computing subsystem 82, utilizing the rules set 84 and acting on information in the database 86 and the known location of the user terminal from the position-location subsystem 90, is enabled to thus provide individual user terminal by individual user terminal instructions to the transmitter control unit 78 so as to control the number of gateway antenna/transmitter pairs that send a traffic signal transmission (19a, 17a) to the user terminal receiver via the selected number of satellite repeaters 12.

A further refinement of path diversity control is implemented by a knowledge of the historical use of power by the user terminals 13. For example, in most mobile communications systems using satellites the individual traffic signals of the user terminal are actively power controlled such that sufficient margin to overcome shadowing and blocking is provided on a link-by-link basis. Such power control loops operate on both the forward and return links, and may be open or closed loops. In any case, the power control loops may be monitored and data recovered by the gateway 18 that is used to determine the historical utilization of power, and therefore, the user terminal environment. It is possible to determine, in a general manner, the type of blocking or shadowing that is being experienced. For example, a link which is blocked (has an extremely deep fade) for a hand-held terminal 14 for minutes at a time can be deduced to be caused by a building or some other Radio Frequency (RF) opaque object.

On the other hand, a rapidly varying sequence of fades from substantially zero to deep fading may signify a vehicle moving through a heavily treed environment. This historical power control-related data is used to make decisions relative to the delivery of path diversity. Likewise, certain users may historically use more power per call than others, leading to a desire to either provide, or deprive, that user terminal of diversity according to need. This historical power control data may be of a long term or short term average nature.

The methods for selecting path diversity described above may be used separately, or combined in multiple ways, and may be dynamically or semi-dynamically assigned. For example, user terminals 13 may be selected initially to be supplied with "all satellite available" diversity equally, effectively bypassing the path diversity selection system 70 altogether. Alternatively, upon instructions from the satellite loading and resource subsystem 88, the computing subsystem 82, under control of the rules set 84, may determine that selective path diversity is required in order to conserve power or manage the FDM frequency allocation of the satellites 12. The computing subsystem 82, under the control of the rules set 84, then decides on a link-by-link basis, or alternatively on a user terminal group basis, which path diversity mode to operate in. The various modes and refinements of path diversity control, as described above, can be utilized either singularly or in any combinations, as necessary to achieve the goals of the instructions of the satellite loading and resource subsystem 88.

As such, it is a feature of this invention that the user terminals 13 are actively diversity controlled much in the same manner as the user terminals are power controlled, via an open or closed loop path diversity control loop, which is used to deliver near instantaneous changes in link diversity in response to received information.

The capacity of satellite communication systems is generally limited by both the bandwidth and the power available in the satellites. The bandwidth utilization and power availability depend in part on the diversity provided to the user terminals 13 on the system. While the discussion above generally pertains to the improvement of the reception of signals by the user terminals 13, the opposite effect can also be achieved by the invention described herein. For example, the path diversity control of individual user terminals 13, sub-groups of user terminals 13, or entire groups of user terminals 13 may be employed to dynamically increase the capacity of the system and/or to affect the power utilization of the system. The instructions from the satellite loading and resource subsystem 88, acted on by the rules set 84 in the computing subsystem 82, may also be used to control the utilization of individual ones of the satellite resources.

The discussion thus far has generally treated the forward link, i.e., the communication path from the gateway 18 to a user terminal 13, via one or more of the satellite repeaters 12. The ensuing discussion will pertain, instead, to the reverse or return link. The return link is defined as follows and is shown in Fig. 8. A user terminal 13 takes a single input and forwards this to a transmitter which amplifies the signal and delivers the amplified signal to its antenna 13a for transmission simultaneously on the same frequency to the satellite repeaters 12. The satellite repeaters receive antennas 12c receive the signals, not necessarily simultaneously, and transmit the signals to the ground via transmit antennas 12g (see also Fig. 3A). The transmitted signals are received at the gateway 18 by three independent receive antennas 40a-40c and sent to their respective receivers 44a-44c. The received signals may then be processed and combined as described in, by example, U.S. Patent 5,233,626, which has been incorporated by reference herein.

The return link may be used for determining the user terminal power activity 74 (Fig. 7), although the forward link power control activity may be used for this purpose as well. The return link may also be used to transmit the user terminal type 76 (Fig. 7), although this information may be derived from a database of inactive or active users on the system, such as by correlating the user terminal's Electronic Serial Number (ESN) with an associated and predetermined user terminal type. The return link may also be used to transmit the user position location 72 (Fig. 7) for use in making

diversity decisions by the computing subsystem 82. In this case the user terminal 13 transmits a signal on this return link bearing information which may be used by the gateway 18 to determine the location of the user terminal 13. Alternatively, the user terminal 13 can transmit its location by the use of some code. In another embodiment of this invention any of the well-known types of radio location systems (such as the various GPS position location devices) may be used to determine the location of the user terminal 13, after which the user terminal location information 72 is transmitted over the return link to the gateway 18 and thence to the position location subsystem 90 (Fig. 7).

As mentioned previously, the return link may also have path diversity selectivity in accordance with the teachings of this invention, so long as the user terminal 13 has the ability to simultaneously direct its signals to one or more of the satellite repeaters 12. In this case, the operation of the system involves cooperation of the gateway 18 and the user terminal 13 in the following manner.

As was described in detail above, the user terminal type 76, the user position location 72, and the user terminal power activity 74 are determined and processed by the computing subsystem 82 and instructions are issued to the instruction interface 80. The instruction interface 80 decodes the instructions and generates suitable control signals for the transmitter control unit 78 and the return link control unit 96. In this case the control signal generated for the return link control unit 96 causes a signal 96a to be formatted and delivered to the terminal frequency control unit 64 of the diversity path delivery system 60. The terminal frequency control unit 64 in turn generates a control signal containing the information that is necessary to control the antenna/amplifier combination at the user terminal 13. This signal is sent to the user terminal 13 receiver over the forward link.

As is shown in Fig. 9, the control signal 102 is received at the user terminal 13 and is routed to an antenna selector 104 which then controls the antennas 13a, 13a', 13a", etc., to achieve the desired results. That is, in this embodiment control over the user terminal 13 antennas 13a-13a", and hence control over the return link path diversity, is accomplished by remote control from the gateway 18, using the forward link as a control link.

Reference is now made to Fig. 10 for showing a portion of an exemplary service area propagation, or communications environment, map 92. In this exemplary digitized map, which may be derived from satellite images of the gateway service area, there is located a lake region, a forest region, a rural region, and an urban region. These different regions may be classified into three general types of Environmental Regions (ERs) in accordance with a level of path diversity that is anticipated to provide a stationary user terminal 13 with an adequate and acceptable link quality. By example, the lake region is designated as ER1, which corresponds to no diversity (i.e., one satellite repeater). The rural area is designated as ER2, which corresponds to an intermediate level of path diversity. The forest region and the urban region are both designated as ER3, which may correspond to a maximum available path diversity level (i.e., the communication link is established through as many satellites 12 as is possible, depending on system loading and other criteria).

Plotted on the map 92 are the current locations of 14 active user terminals (UT1-UT14). Assuming as a simplest case that three satellite repeaters 12 are currently serving this area, that all of the user terminals 13 are of the same type, and that other factors such as historical power control information, season variations, local weather conditions, etc. are not considered, then UT1 is assigned one of the satellite repeaters 12, UT3 and UT4 are assigned two of the satellite repeaters 12, and UT2 and UTs 5-14 are each assigned three of the satellite repeaters 12. It can thus be appreciated that by not automatically assigning the maximum available path diversity to user terminals UT1, UT3 and UT4, a considerable savings in satellite power consumption is realized, as is a conservation of the number of required RF channels and a general increase in total system capacity.

Further in accordance with the invention the relatively static system profile described thus far can be extended to the more typical dynamic case, while still optimizing the path diversity delivered to the user terminals 13. For example, if UT2 is a mobile, vehicle mounted terminal 15, then by detecting that the location of UT2 has changed from ER3 to ER2 the assigned path diversity can be changed in real time or substantially real time from three satellites to two, while still maintaining the same user-perceived link quality. Conversely, if the location of UT4 changes from ER2 to ER3 the assigned path diversity can be changed from two satellites to three. Furthermore, if it is known that several of the UTs 5-14 are fixed user terminals 14a, which are assumed to have antennas that are located in a region free of signal-blocking obstructions, then these user terminals can be assigned but a single satellite, although they are located within an ER3 portion of the gateway 18 service area. Also by example, the forested region can be designated as an ER3 region during the months of May through October, and designated as an ER2 region during the months of November through April.

The rules set 84 of Fig. 7 determines the path diversity level for the user terminals UT1-UT14 as described previously. The rules set 84 can be implemented as a set of IF-THEN-ELSE type of logical statements. By example, the following is but one suitable embodiment for a portion of the rules set 84 in determining a Diversity Level (DL) for user terminals 13.

```

5      IF TYPE of UTi = HANDHELD and
      IF LOCATION of UTi = ER1
      THEN DL = MINIMUM
      ELSE IF LOCATION of UTi = ER2
      THEN DL = INTERMEDIATE
      ELSE IF LOCATION of UTi = ER3
      THEN DL = MAXIMUM

10     ELSE
      IF TYPE of UTi = FIXED
      THEN DL = MINIMUM
      ELSE
15      IF TYPE of UTi = DATA TERMINAL and
      IF LOCATION of UTi = ER1
      THEN DL = INTERMEDIATE
      ELSE IF LOCATION of UTi = ER2 OR ER3
      THEN DL = MAXIMUM

etc...
20

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The data terminal type of user terminal 13 illustrates the utility of the invention in assigning a diversity level based on both terminal type and location. By example, it may be desirable to automatically assign higher diversity to a user terminal that is identified as a data terminal, or to a voice terminal that is identified as being involved in a data transmission, so as to provide additional margin to avoid an erroneous data transmission.

As described previously, other criteria can be considered in the rules set 84 when determining a diversity level, such as historical power control information, the historical usage data 77, local weather conditions, and any other factors that are related to or that can influence the link quality.

It should be noted that determined level of diversity for a given user terminal may differ from the actual diversity level delivered to the user terminal. By example, if only two satellites 12 are currently in view of the gateway service area then the minimum diversity level may be one satellite while the intermediate and maximum diversity levels may both be set at two satellites. Further, even if only one satellite is in view of the user terminal 13, the gateway 18 and user terminal 13 may be able to utilize signals from two overlapping beams. Since the geometry of the satellites is known, this invention can control and employ transmissions to more than one beam. Also by example, during periods of high user demand, and assuming that three satellites are currently serving the gateway service area, the intermediate and maximum diversity levels may still both be set at two satellites. The translation of determined diversity level into an actual diversity assignment for a given user terminal 13 or class of user terminals is accomplished by the computing subsection 82, in cooperation with the satellite loading and resource subsystem 88.

Fig. 11 is flow chart of a method of this invention. At block A a user terminal 13 logs on or, if already logged on, initiates a call or is called. At block B the user terminal type 76 is determined, and at block C the location 72 of the user terminal is determined. At optional block D other user terminal parameters are determined, such as historical power control information 74, historical usage 77, weather conditions at the determined location of the user terminal, etc. At block E the computing subsystem 82 determines, via the database 86 and position location subsystem 90, the diversity level for the user terminal 13. The diversity level is determined in cooperation with the rules set 84, the user position location 72, the user terminal type 76, optional user terminal related information, such as the terminal power activity 74, the service area propagation map 92, and in accordance with the satellite loading and resource system 88. At block F the call is established with a selected diversity level via the instruction interface 80, the transmitter control unit 78, path diversity delivery system 60 and, optionally, through the return link control unit 96 and terminal frequency control unit 64. At block J the system senses and reports increased/decreased power control activity and, after a suitable delay, at block K increases or decreases the path diversity accordingly. At block G a determination is made if the call is completed. If NO, control returns to block C, for a user terminal type that is capable of movement, to update the user terminal position and to modify the path diversity level (block E) if appropriate. If YES at block G an optional step (block H) is executed to store or log selected user terminal parameters, such as the terminal power activity, last location of the user terminal, etc. At block I the method terminates for this user terminal.

It can be appreciated that the teaching of this invention provides a number of significant advantages to any type of communication system that employs diversity combining through intermediate signal repeaters. That is, the teaching of this invention is not limited for use only with the SS-CDMA type of LEO satellite communication system 10 that is shown generally in Figs. 1-5. Instead, the teaching of this invention is applicable to other types of communications systems that

use, by example, terrestrial repeaters either alone or in combination with satellite (LEO or geosynchronous) repeaters. The teaching of this invention is also applicable to other access types, such as TDMA, that use diversity in some manner.

Thus, while the invention has been particularly shown and described with respect to preferred embodiments thereof, it will be understood by those skilled in the art that changes in form and details may be made therein without departing from the scope and spirit of the invention.

Claims

- 10 1. A communications system, comprising:
 - at least one communication signal repeater;
 - 15 a communication signal transmitter having a plurality of antennas for selectively transmitting a communication signal to said at least one communication signal repeater;
 - a communication signal receiver for receiving a communication signal from said communication signal transmitter through said at least one communication signal repeater; and
 - 20 control means, responsive to information specifying at least a location of said communication signal receiver, for specifying a number of said communication signal repeaters to be used in repeating a communication signal that is transmitted from said transmitter to said receiver via said specified number of communication signal repeaters.
- 25 2. A communication system as set forth in claim 1 wherein said control means is further responsive to information that specifies a communication signal receiver type for specifying the number of said communication signal repeaters to be used in repeating the communication signal that is transmitted from said transmitter to said receiver.
- 30 3. A communication system as set forth in claim 1 wherein said receiver is a component of a transceiver having a transmitter capable of being remotely power controlled, and wherein said control means is further responsive to information specifying a power control history for said transmitter of said transceiver for specifying the number of said communication signal repeaters to be used in repeating the communication signal that is transmitted from said transmitter to said receiver.
- 35 4. A system as set forth in claim 1 wherein the information specifying a location of said communication signal receiver includes information that specifies an RF energy propagation characteristic that is associated with an environment within which the communications signal receiver is located.
- 40 5. A system as set forth in claim 1 wherein said at least one communication signal repeater is one of a plurality of earth orbiting satellites.
6. A system as set forth in claim 5 wherein said plurality of earth orbiting satellites form a portion of a constellation of low earth orbit (LEO) satellites.
- 45 7. A communication system as set forth in claim 5 wherein said control means is further responsive to information that specifies a current availability of said plurality of earth orbiting satellites for specifying the number of said communication signal repeaters to be used in repeating the communication signal that is transmitted from said transmitter to said receiver.
- 50 8. A communication system as set forth in claim 1 wherein said control means is further responsive at least to information that specifies a current availability of said plurality of earth orbiting satellites for specifying a number of beams of said communication signal repeaters to be used in repeating the communication signal that is transmitted from said transmitter to said receiver.
- 55 9. A communication system as set forth in claim 1 wherein said transmitter is a component of a ground station transceiver having a ground-based receiver for receiving user communications via said at least one communication signal repeater, wherein said receiver is a component of a user transceiver having a transmitter and antenna that is capable of directing a transmission towards at least one of said communication signal repeaters to be relayed to said ground-based receiver, and wherein said control means is capable of selecting at least one of said commun-

cation signal repeaters for relaying a communication from said user transceiver to said ground-based receiver, and further including means for transmitting a message to said user transceiver for controlling said antenna of said user transceiver for transmitting the communication towards a selected one of said communication signal repeaters.

5 10. A communications system, comprising:

a plurality of communication signal repeaters;

10 a communication signal transmitter having a plurality of antennas for selectively transmitting a communication signal to individual ones of said communication signal repeaters;

a communication signal receiver for receiving a communication signal from said communication signal transmitter through at least one of said communication signal repeaters; and

15 control means, responsive to information specifying at least a type of said communication signal receiver, for specifying a number of said communication signal repeaters to be used in repeating a communication signal that is transmitted from said transmitter to said receiver.

20 11. A communication system as set forth in claim 10 wherein said control means is further responsive to information that specifies a location of said communication signal receiver for specifying the number of said communication signal repeaters to be used in repeating the communication signal that is transmitted from said transmitter to said receiver.

25 12. A communication system as set forth in claim 10 wherein said control means is further responsive to information that specifies an environment of said communication signal receiver for specifying the number of said communication signal repeaters to be used in repeating the communication signal that is transmitted from said transmitter to said receiver.

30 13. A communication system as set forth in claim 10 wherein said control means is further responsive to information that specifies a historical usage of the system by the communication signal receiver for specifying the number of said communication signal repeaters to be used in repeating the communication signal that is transmitted from said transmitter to said receiver.

35 14. A communication system as set forth in claim 10 wherein said receiver is a component of a transceiver having a transmitter capable of being remotely power controlled, and wherein said control means is further responsive to information specifying a power control history for said transmitter of said transceiver for specifying the number of said communication signal repeaters to be used in repeating the communication signal that is transmitted from said transmitter to said receiver.

40 15. A system as set forth in claim 11 wherein the information specifying a location of said communication signal receiver includes information that specifies an RF energy propagation characteristic that is associated with an environment within which the communications signal receiver is located.

45 16. A system as set forth in claim 10 wherein said plurality of communication signal repeaters are comprised of a plurality of earth orbiting satellites.

17. A system as set forth in claim 16 wherein said plurality of earth orbiting satellites form a portion of a constellation of low earth orbit (LEO) satellites.

50 18. A communication system as set forth in claim 16 wherein said control means is further responsive to information that specifies a current availability of said plurality of earth orbiting satellites for specifying the number of said communication signal repeaters to be used in repeating the communication signal that is transmitted from said transmitter to said receiver.

55 19. A method of operating a satellite communication system, comprising the steps of:

initiating a communication between a user terminal and a ground station via at least one satellite communication signal repeater;

determining a location of the user terminal within a area serviced by the ground station; and

5 selecting a number of satellite communication signal repeaters to relay the communication between the user terminal and the ground station, the selected number being a function of at least the determined location of the user terminal.

20. A method as set forth in claim 19 wherein the step of selecting includes a step of determining an RF energy propagation characteristic that is associated with the determined location of the user terminal.
- 10 21. A method as set forth in claim 19 wherein the step of selecting includes a step of classifying the user terminal as to type.
22. A method as set forth in claim 19 wherein the step of selecting includes a step of considering a power control history of the user terminal.
- 15 23. A method as set forth in claim 19 wherein the step of selecting includes a step of considering a current availability of satellite communication signal repeaters.
- 20 24. A method as set forth in claim 19 wherein the step of selecting includes a step of considering a system usage historical record of the user terminal.
- 25 25. A method as set forth in claim 19 wherein the communication is bidirectionally relayed as a spread spectrum, code division multiple access communication signal between the user terminal and the ground station.
26. A method as set forth in claim 19 and further comprising the steps of:
 - receiving the communication with the user terminal, the communication being received through different communication paths associated with individual ones of the selected number of satellite communication signal repeaters;
 - 30 equalizing at least the phase shifts and delays of the received communication from each of the different paths to provide a plurality of equalized communication signals; and
 - 35 combining the equalized communication signals into a composite received communication signal.
27. A method of operating a satellite communication system, comprising the steps of:
 - initiating a communication between a user terminal and a ground station via at least one satellite communication signal repeater;
 - 40 classifying the user terminal as to type; and
 - selecting a number of satellite communication signal repeaters to relay the communication between the user terminal and the ground station, the selected number being a function of at least the type of the user terminal.
- 45 28. A method as set forth in claim 27 wherein the step of selecting further includes a step of determining a location of the user terminal within an area serviced by the ground station.
29. A method as set forth in claim 28 wherein the step of selecting includes a step of determining an RF energy propagation characteristic that is associated with the determined location of the user terminal.
- 50 30. A method as set forth in claim 27 wherein the step of selecting includes a step of considering a power control history of the user terminal.
- 55 31. A method as set forth in claim 27 wherein the step of selecting includes a step of considering a system usage history of the user terminal.
32. A method as set forth in claim 27 wherein the step of selecting includes a step of considering an availability of satellite communication signal repeaters.

33. A method as set forth in claim 27 wherein the communication is bidirectionally relayed as a spread spectrum, code division multiple access communication signal between the user terminal and the ground station.

34. A method as set forth in claim 27 and further comprising the steps of:

5 receiving the communication with the user terminal, the communication being received through different communication paths associated with individual ones of the selected number of satellite communication signal repeaters;

10 equalizing at least the phase shifts and delays of the received communication from each of the different paths to provide a plurality of equalized communication signals; and

combining the equalized communication signals into a composite received communication signal.

15 35. A method of operating a satellite communication system, comprising the steps of:

initiating a communication between a user terminal and a ground station via at least one satellite communication signal repeater;

20 selecting at least one satellite communication signal repeater to relay a return link communication between the user terminal and the ground station; and

transmitting a message from the ground station to the user terminal over a forward link, the message controlling the user terminal to transmit the return link communication through the selected at least one satellite communication signal repeater.

25

36. A satellite communication system, comprising:

30 a plurality of communication satellites;

a ground station comprising a transceiver for transmitting and receiving communication signals with individual ones of said plurality of communication satellites;

35 at least one user terminal comprising a transceiver for transmitting and receiving communication signals with individual ones of said plurality of communication satellites;

said ground station further comprising a data base of user terminal-related information including information specifying, for individual user terminals, at least a type of user terminal, said data base further storing information that is descriptive of an RF propagation characteristic of one or more regions within a service area of said ground station;

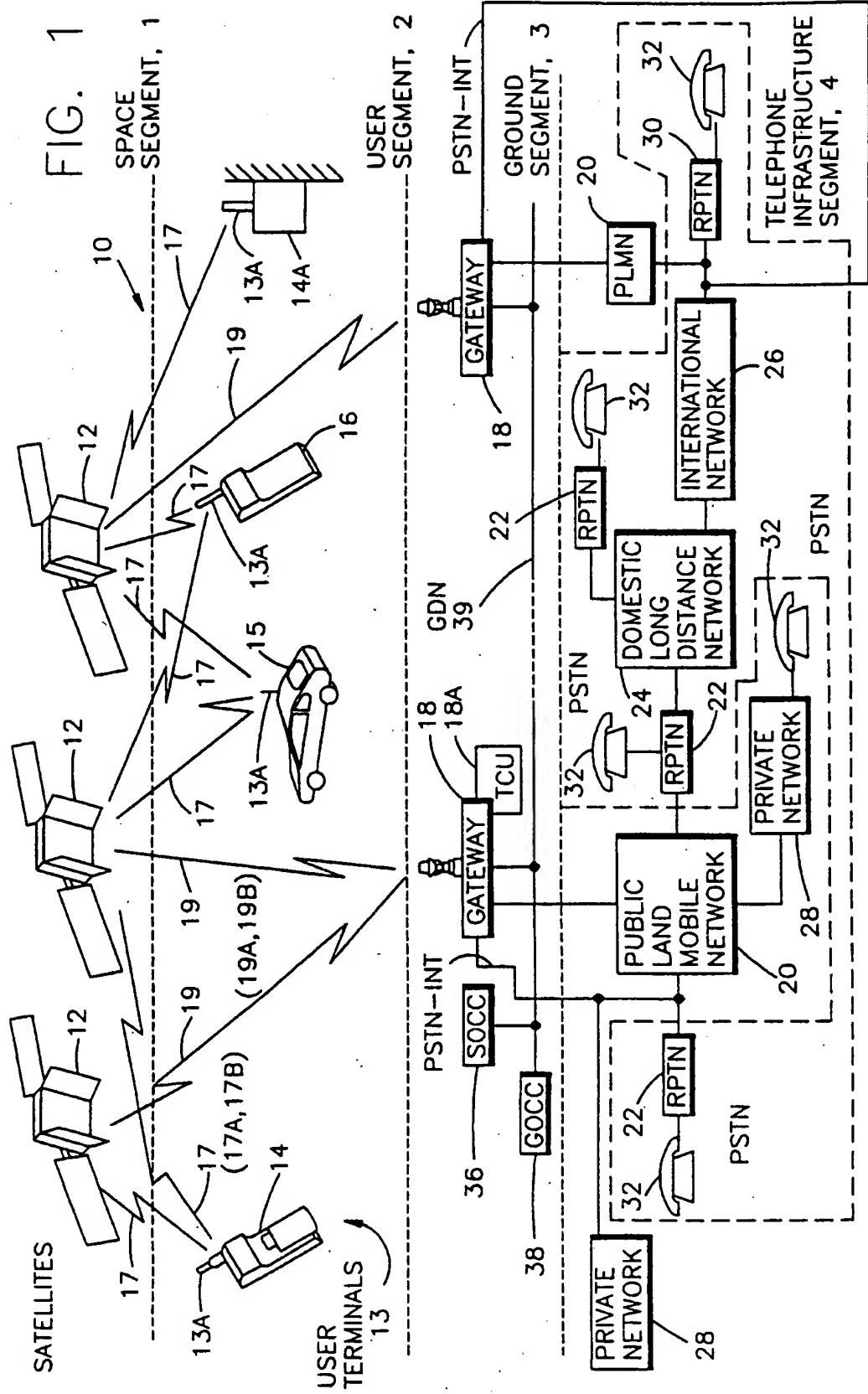
40

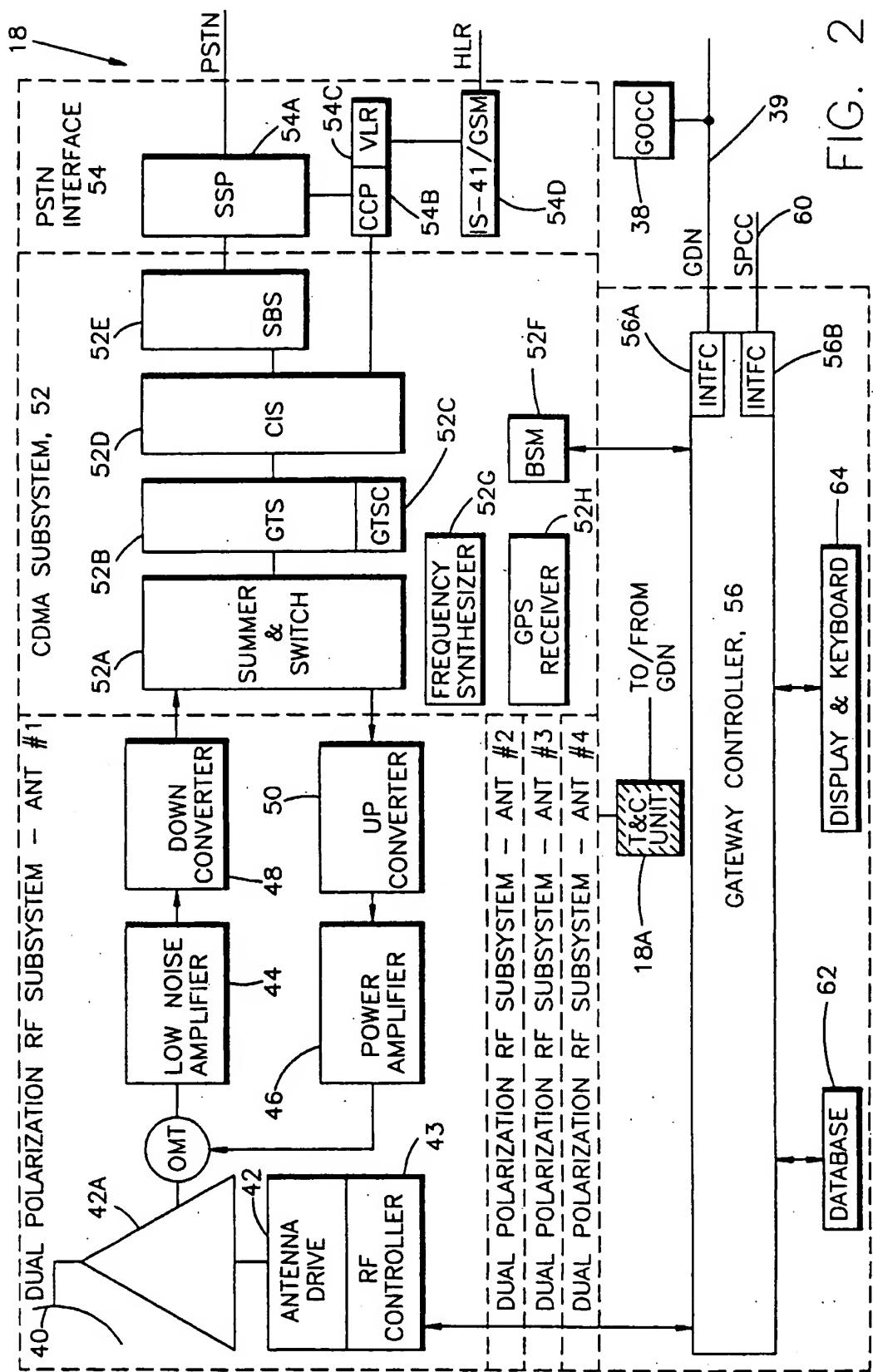
45 said ground station further comprising control means that is coupled to said data base and to a rules set for determining a number of communication satellites for relaying a communication between individual ones of said user terminals and said ground station, said ground station including means for determining a location of individual ones of said user terminals, and wherein said control means determines the number of communication satellites in accordance with at least one of a user terminal type, a user terminal location, and an RF propagation characteristic that is associated with a location of said user terminal.

37. A satellite communication system as set forth in claim 36, wherein said data base further stores information that is descriptive of user terminal historical power control activity.

50 38. A satellite communication system as set forth in claim 36, wherein said data base further stores information that is descriptive of user terminal historical system usage.

55 39. A satellite communication system as set forth in claim 36, wherein said plurality of communication satellites comprise a Walker constellation of low earth orbit satellites, and wherein communications are bidirectionally transmitted as spread spectrum, code division multiple access communication signals between a user terminal's transceiver and the ground station's transceiver, through at least one of said plurality of communication satellites.





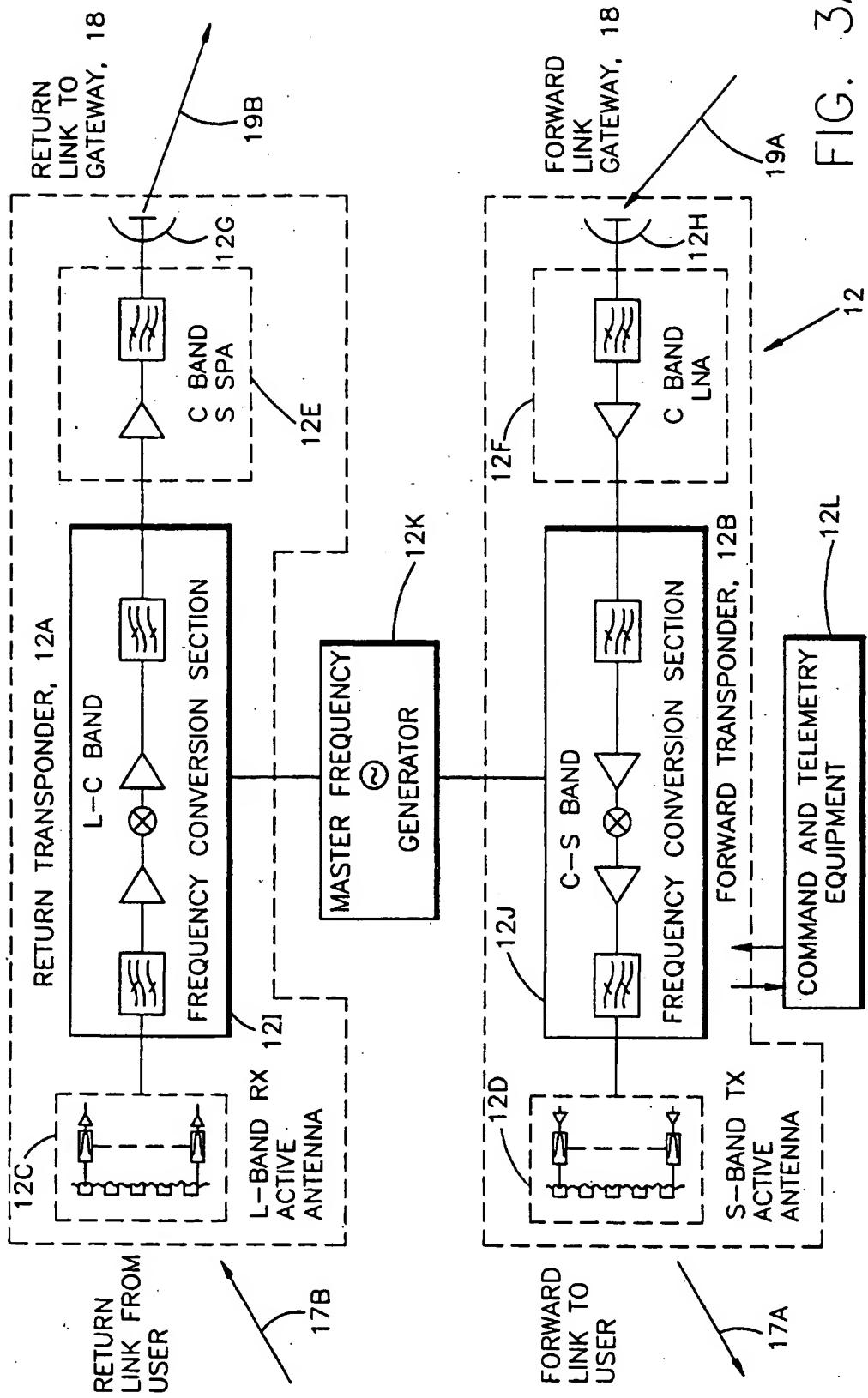


FIG. 3A

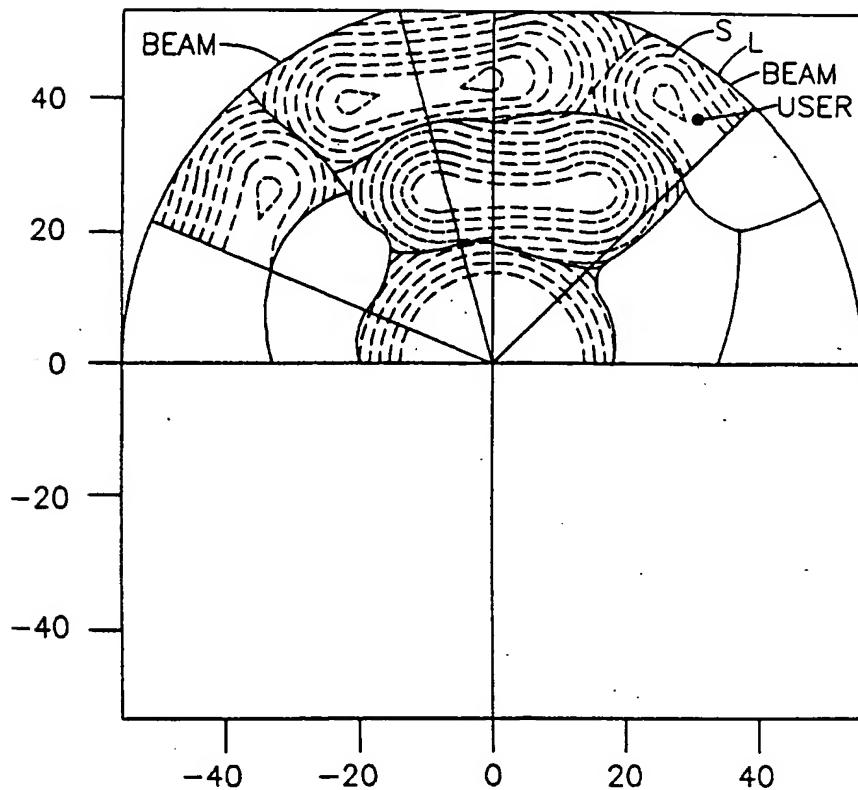
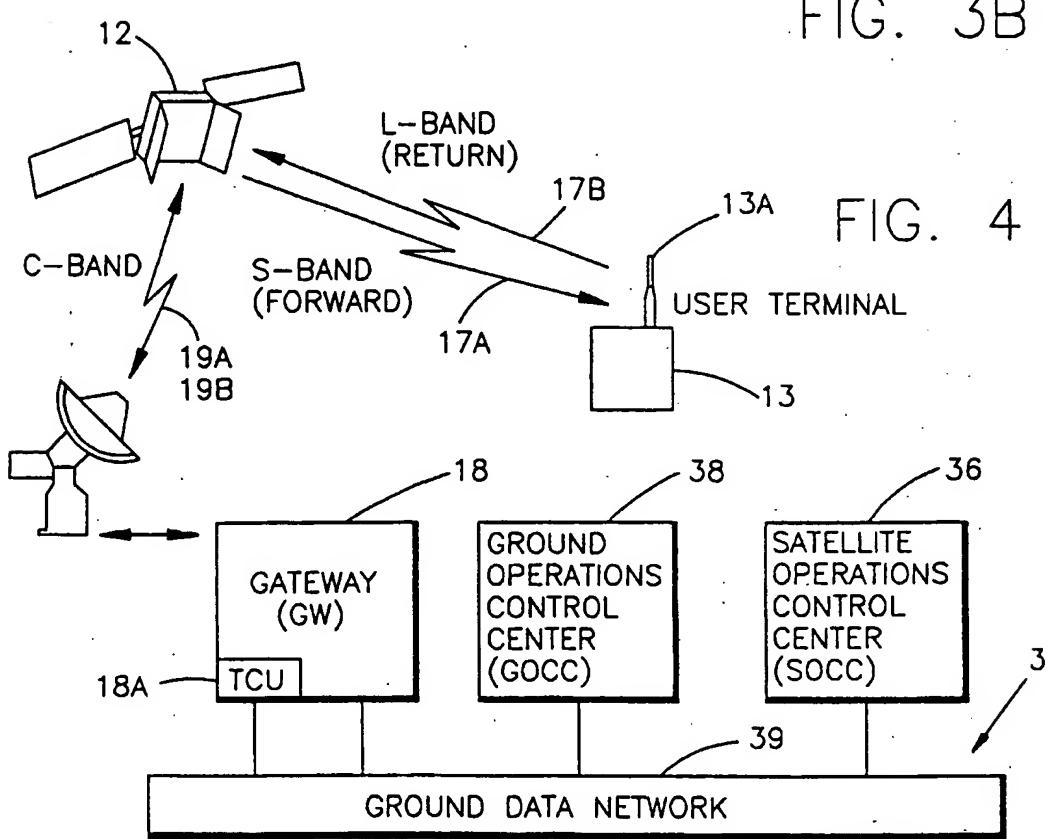


FIG. 3B



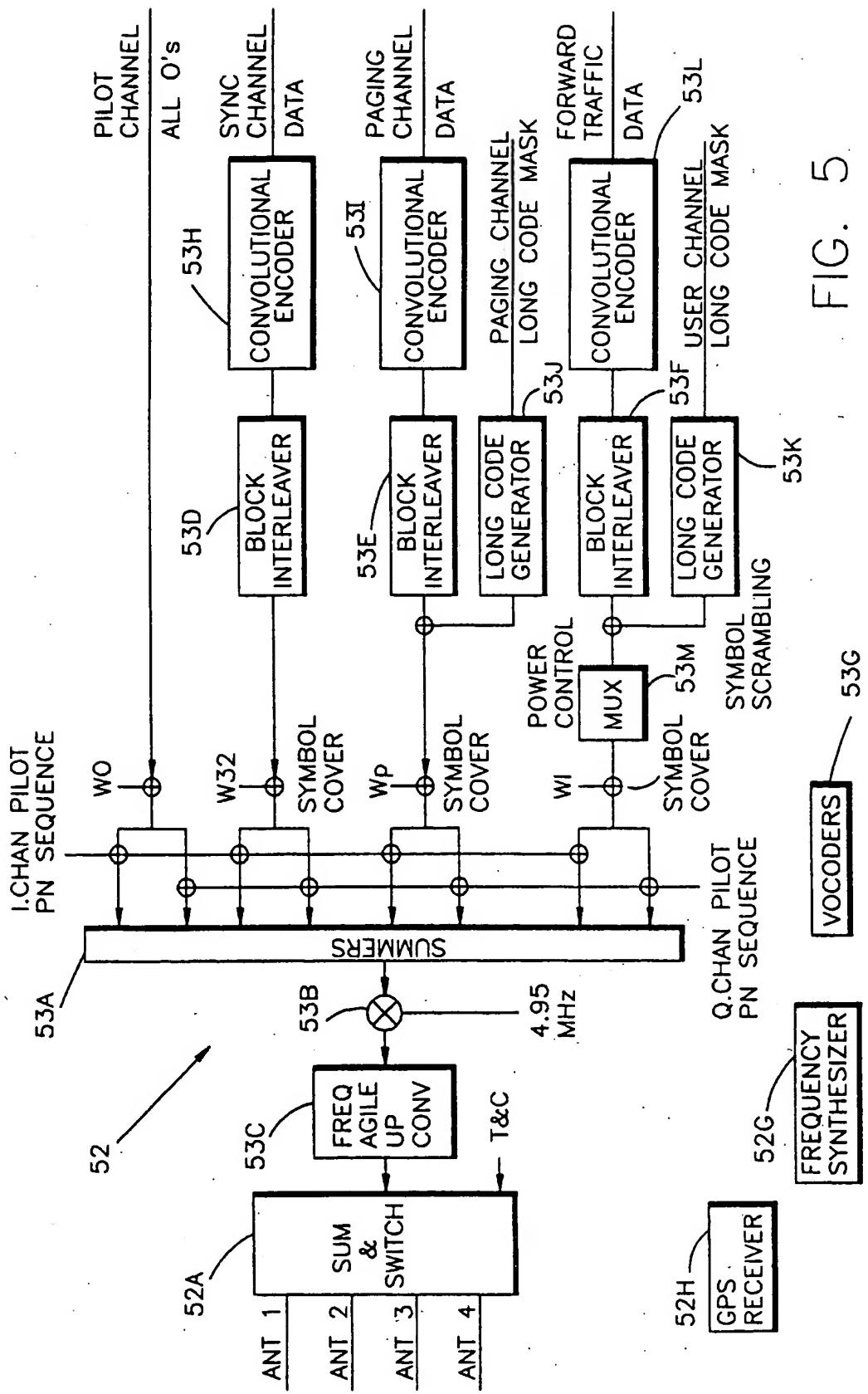


FIG. 5

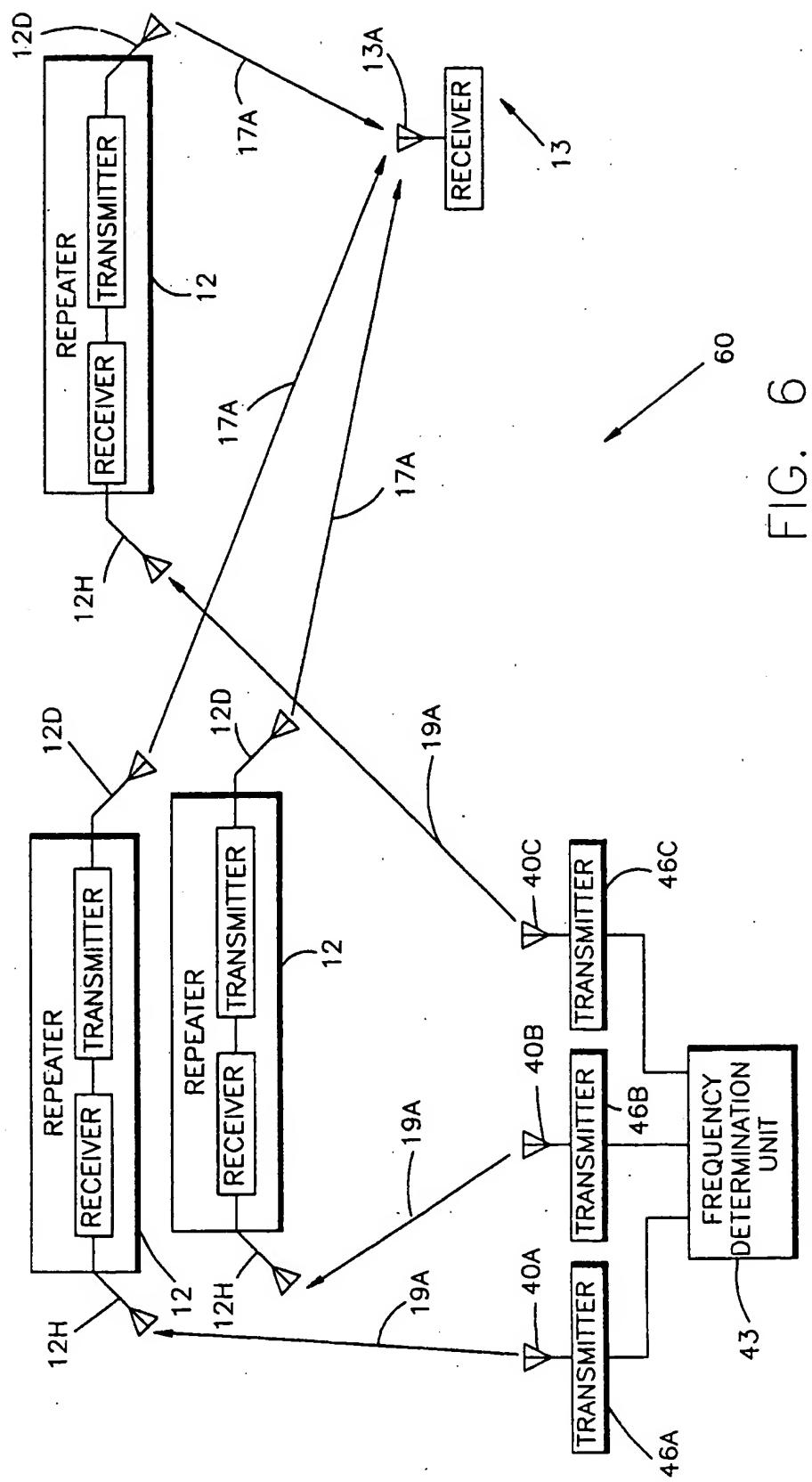


FIG. 6

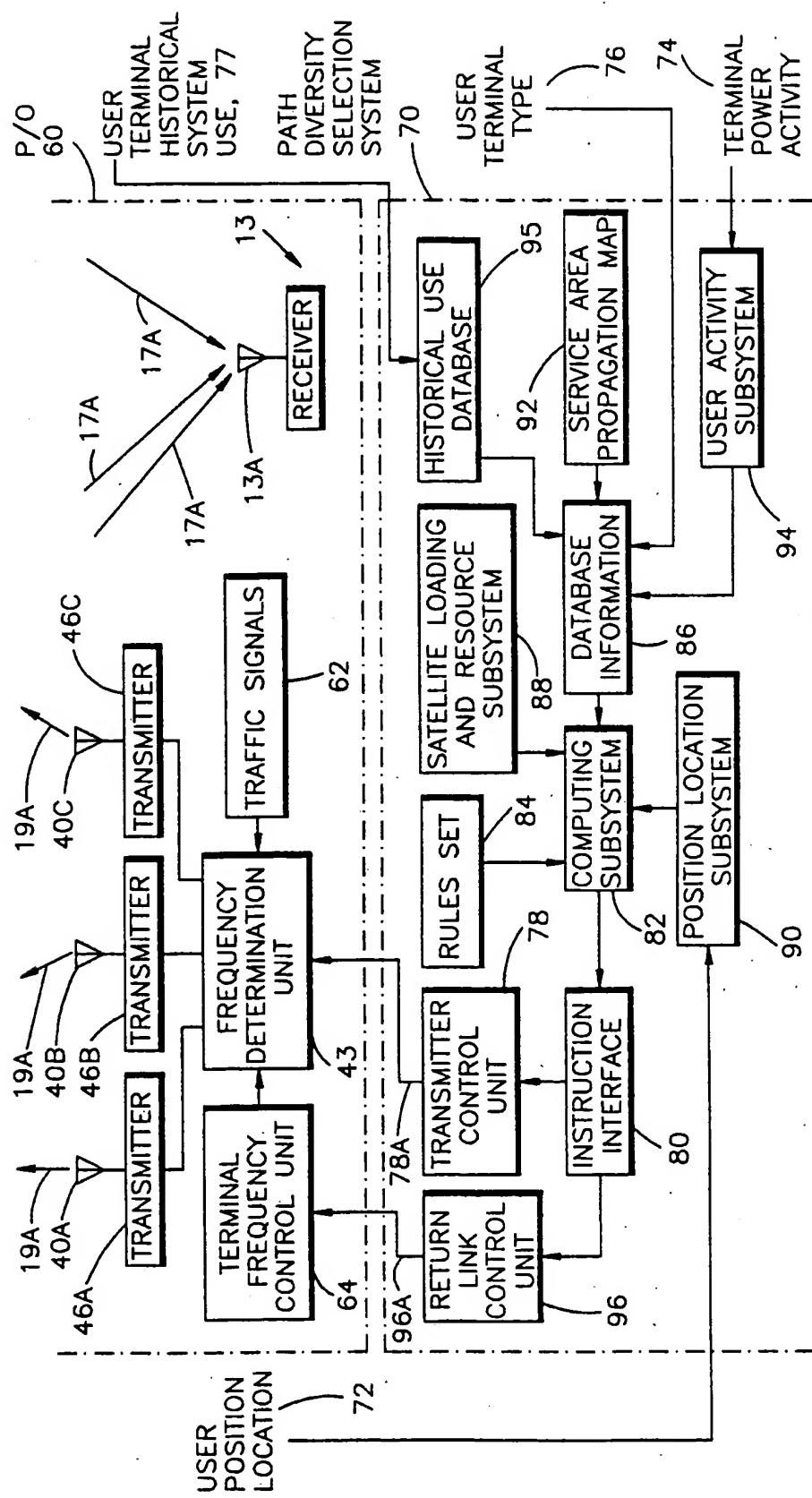


FIG. 7

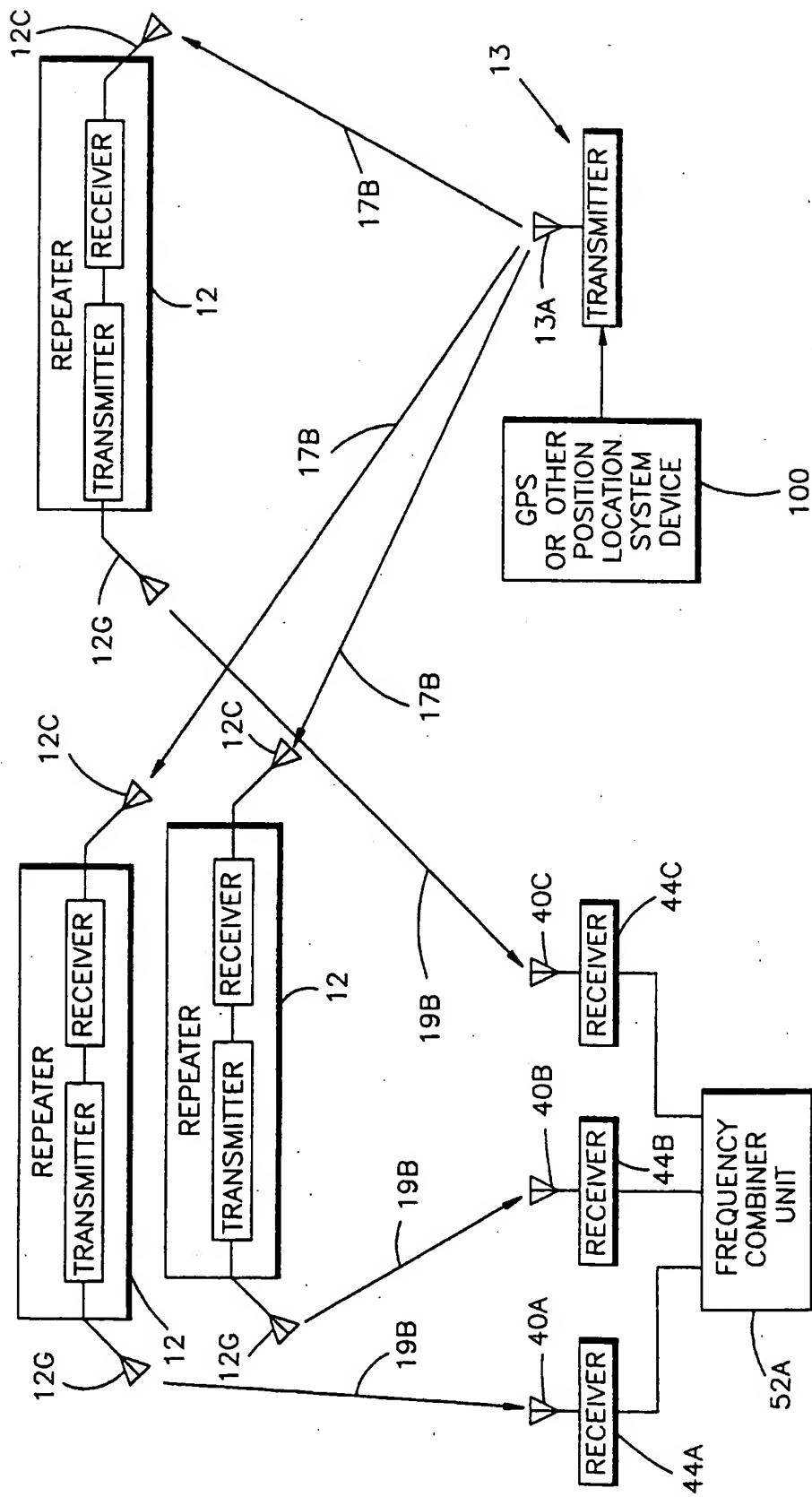


FIG. 8

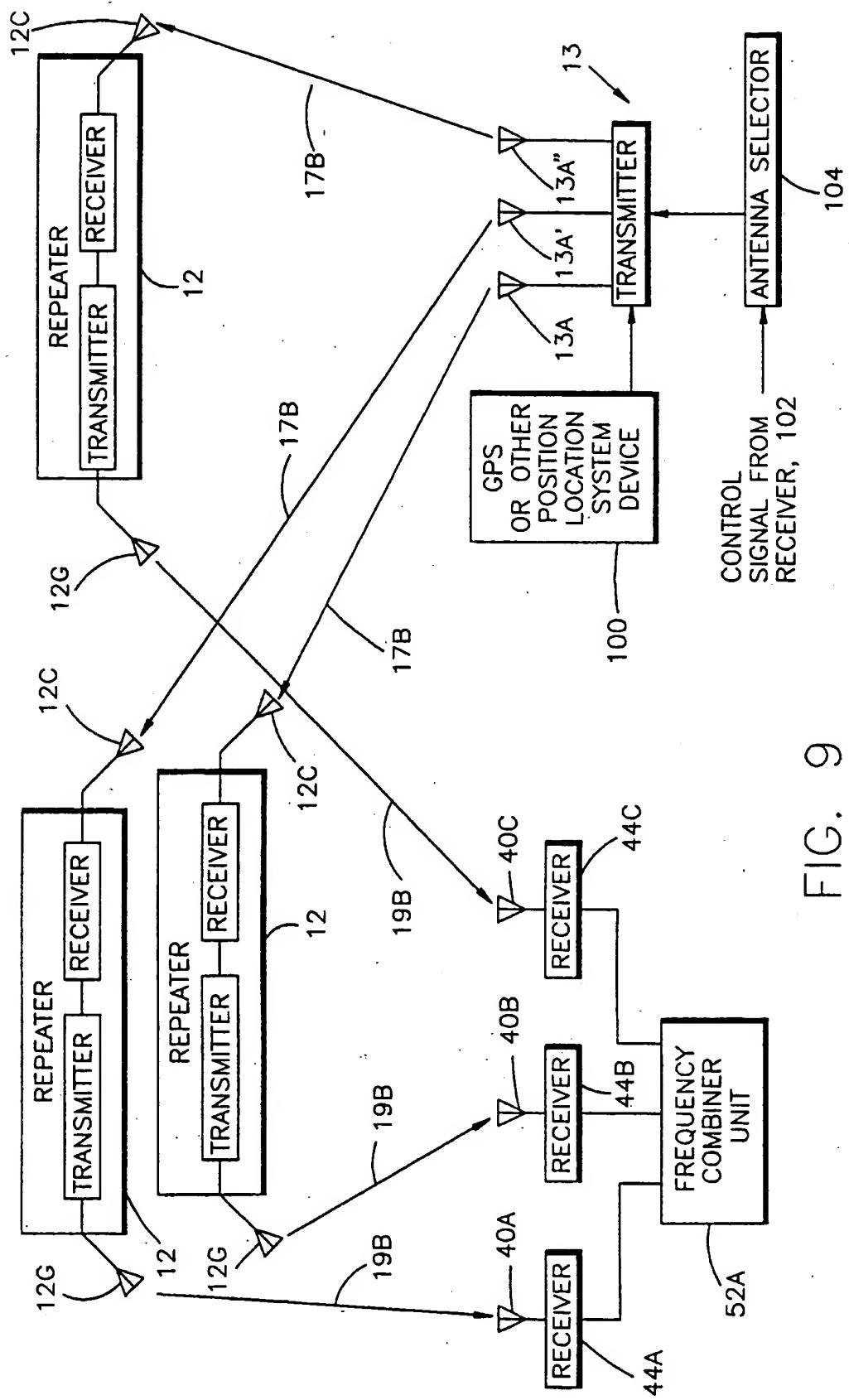


FIG. 9

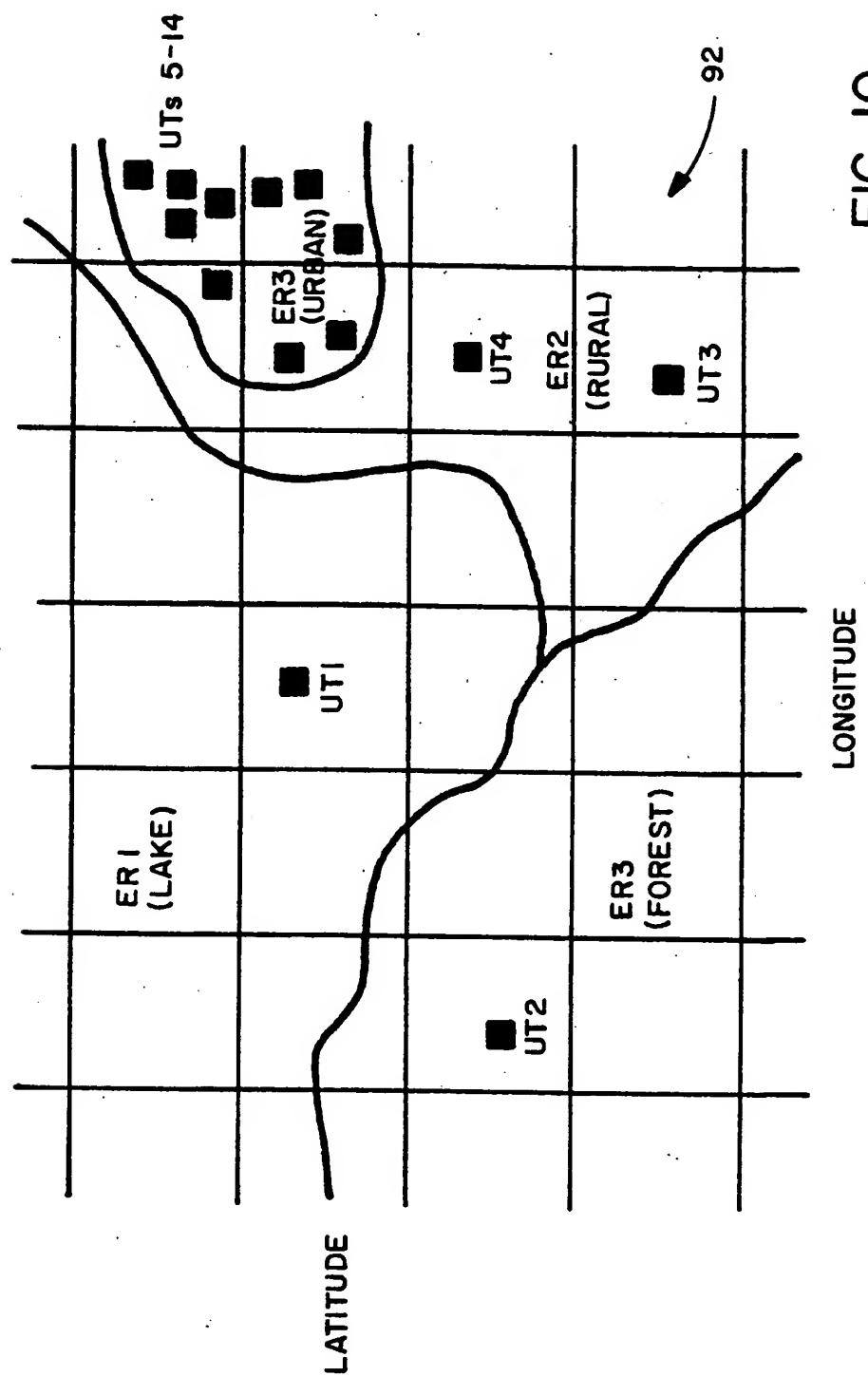


FIG. 10

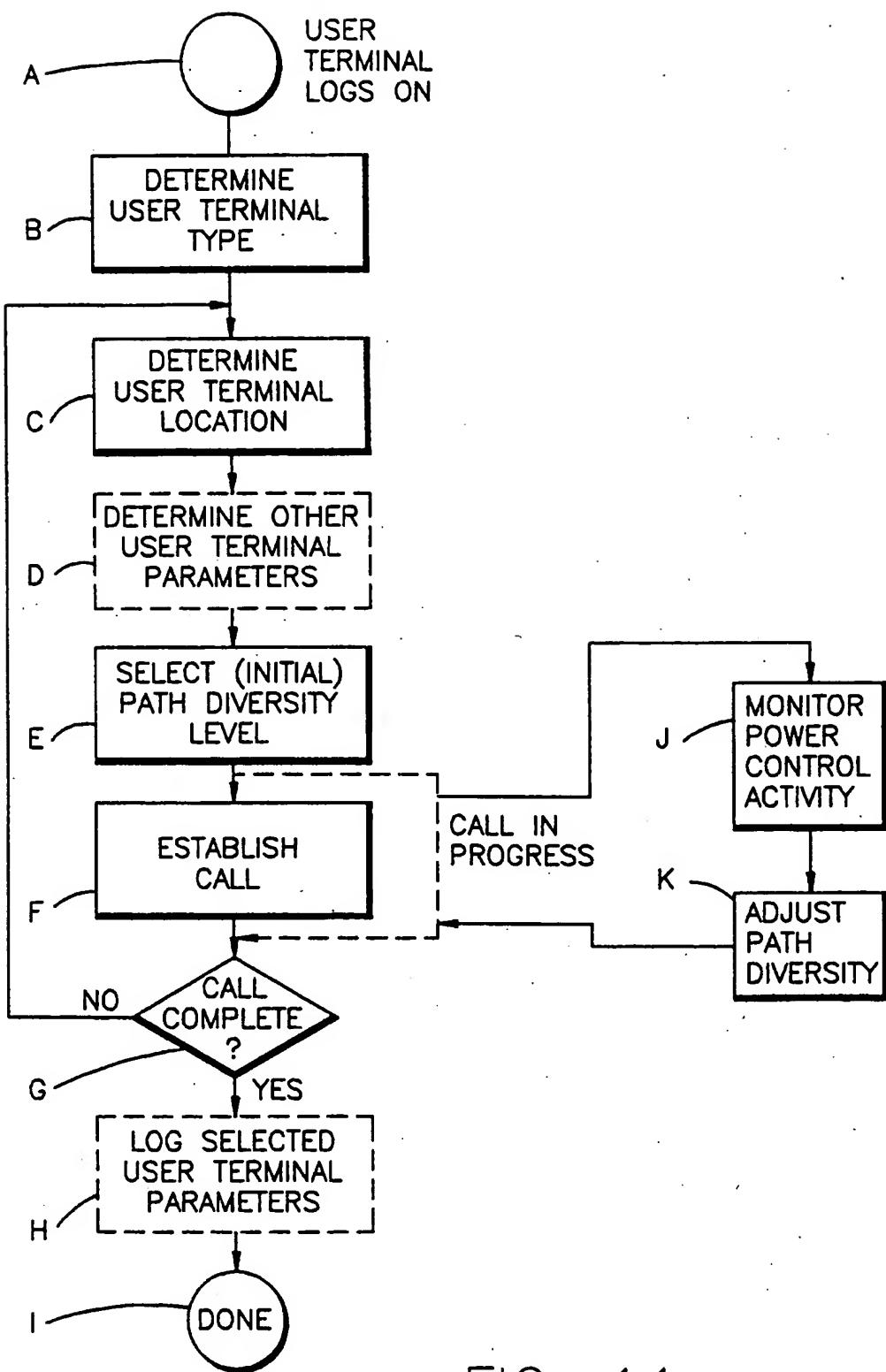


FIG. 11

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